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SEPTEMBER-OCTOBER 1960

VOLUME XI NUMBER 5

OFFICIAL PUBLICATION OF THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS, INC.

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Published Bimonthly **• American Institute of Industrial Engineers, 32 West Fortieth Street, New York 18, New York •** ***Editorial Offices*****—A. French Building, 225 North Avenue, N.W., Atlanta 13, Georgia**

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Subscription Prices: $10.00, one year; $17.00, two years; single issue, $2.50.

All Manuscripts for review should be submitted with drawings suitable for reproduction to the Editor-in-Chief, Journal of Industrial Engineering, A. French Building, 225 North Avenue, N.W., Atlanta 13, Georgia.

Advertising Rates available from Editorial Offices. Send copy and cuts to Journal of Industrial Engineering, A. French Building, 225 North Avenue, N.W., Atlanta 13, Georgia.

Membership Information available from AIIE.

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Second-class postage paid at New York, New York and at additional mailing offices.

Work Sampling—Eleven Fallacies[1]

by **HAROLD O. DAVIDSON**

Vice President, Industrial Engineering, Operations Research, Incorporated

SINCE Tippett's first applications in the British textile industry about 25 years ago, the work sampling technique has been utilized in virtually every industry and in many different kinds of applications. Along with the growth in applications there has come, particularly in the last decade, a considerable volume of published material on the technique. Not all of this has been correct in every detail. Moreover, many practitioners have not had the opportunity for formal study of the technique and, most important, its theoretical foundations. In consequence of these factors there is still considerable uncertainty, or outright misunderstanding, on several points of the theory and practice. In some instances these may lead to unnecessarily complicated or expensive procedures for using the technique or cause erroneous conclusions to be drawn.

This is merely one instance of the general problem facing today's Industrial Engineer—how to keep up with the field? It also concerns the Chief Engineer, whose responsibility it is to build the competence of his staff. A considerable part of this problem is motivational. While this discussion may provide useful information on a number of theoretical points which sometimes give difficulty, it is not a substitute for study of the basic theory. We are of the opinion, however, that the material presented here can be employed in such a way as to provide a motivational stimulus to further study of basic principles.

Over the past ten years or so we have collected a list of fallacies that have appeared in print, either as direct statements or as tacit assumptions by the authors. The material may, of course, be read but a more effective use of it can possibly be achieved in the following manner:

1. Have a suitable number of copies of the list of fallacies prepared in the form of a True-False test.
2. Bring the staff into a pre-arranged meeting and administer the test.
3. Follow up immediately with a discussion of the points covered in each question.

Since the primary purpose is to inform and motivate staff, self-grading of the tests is generally to be recommended.

[1] Based on a presentation to the Work Measurement Conference at the University of Chattanooga on February 13, 1959, under the sponsorship of the Chattanooga Chapter of AIIE and the University.

THE FALLACIES

1. Work sampling works because the law of probability works.
2. Work sampling permits delay allowances to be set with a specified probability that the error will not exceed a predetermined amount.
3. Work sampling is based on the percentage number of delays, not upon their duration.
4. When developing a schedule of observations by use of a table of random numbers, or similar means, one should ignore cases where additional observations are to be taken of the same operator at the same time that an observation is already scheduled.
5. Observations should be separated by a sufficient period of time so that the same delay is not counted twice.
6. As a general rule the number of observations should be such as to provide 95% assurance (2 sigma confidence interval) that the estimated percentage of time devoted to any particular class of activity is within $\pm 10\%$ of the true percentage.
7. If n rounds of observations are taken on a crew composed of k men and an observation is made on each of the k men in each of the n rounds, then the size of the sample to be used in calculating the error of estimate is nk.
8. In nearly all cases the occurrence of delays follows the binomial probability distribution.
9. For a given number of observations, random sampling will have a smaller error variance than any other kind of sampling.
10. Randomization of the times of observation eliminates biases in the estimates of percent time spent in various activities.
11. The main reason for randomizing observation times is that it is necessary to satisfy the requirements of statistical theory used in calculating confidence intervals.

THE FALLACIES EXAMINED

1. *Work sampling works because the law of probability works.* There is a tendency for people to believe that the injection of some mathematics into a procedure makes it "scientific"—and infallible. Unlike public legislators, mathematicians have never devoted themselves to writing "laws" for protection of the careless and unwary. Laymen may speak of "laws" of probability, but mathematicians discuss probability theory. With resourcefulness sometimes and care always in the applications, we can use the "models" provided by this theory as tools for solving practical problems. But we should not forget that mathematical theory is erected entirely on its own abstractions, it is not theory "about" any real phenomena. Insofar as mathematics is concerned, applicability is purely fortuitous; and the validity of an application is something quite separate from the internal validity of the mathematics as Mathematics.

2. *Work sampling permits delay allowances to be set with a specified probability that the error will not exceed a predetermined amount.* Delay allowances are established in order to be applied at some future time after completion of the sampling study. In other words, they

are *forecasts* of future delays. Forecasting requires assumptions, and statistical inference can provide only an ex post facto verification of these assumptions. The error estimates and associated confidence levels obtained from statistical theory apply *only* to the period from which the sample data were obtained.

It is strange that this fallacy has appeared in work sampling applications, though it would be readily recognized in quality control. Suppose, for example, that by sampling inspection of a two-week production run the fraction defective in a certain product was estimated at between 6.3 per cent and 9.1 per cent, with 95% confidence. Could the quality control engineer correctly infer a 95% probability that the fraction defective on this product would run between 6.3 and 9.1 per cent for, say, the next year? If he could, American industry is wasting millions of dollars on superfluous inspection.

3. *Work sampling is based on the percentage number of delays, not upon their duration.* Whether the initial fault of this statement was fallacy, or merely ambiguity, it has in fact produced many fallacious interpretations of sampling principles. The fundamental notion of the existing work sampling technique is, of course, that the probability of an observation detecting any particular category of activity should, with proper design of the sampling plan, be equal to the ratio of the total duration of that activity, in the total study period, to the duration of the total study period. Whether the activity has many occurrences of short duration or a few occurrences of long duration is immaterial to the estimate of percentage delay time, providing the sampling plan is properly designed. (We will show later, however, that the number of delays does influence the *error* of estimate in *systematic* sampling.)

4. *When developing a schedule of observations by use of a table of random numbers, or similar means, one should ignore cases where additional observations are to be taken of the same operator at the same time that an observation is already scheduled.* Those who recommend against "double counting" all use the binomial probability "model" (or the normal approximation to it) in computing the error of estimate. The binomial probability model applies to sampling "with replacement." This means that each member of the "population" must have the same probability of being drawn as every other member of the population at each of the n drawings employed to generate a sample of size n. Thus, the elimination of "double counting" in connection with a binomial probability model actually biases the estimate. Fortunately, if n is small relative to the total number of possible observations in the study period the bias is trivial. Nonetheless, the practice is fallacious and while the effect on results may be negligible there is nothing to be gained from it but extra work in developing the observation schedule.

5. *Observations should be separated by a sufficient interval of time so that the same delay is not counted twice.* While the origin of this advice is unknown it may be related to the notion that work sampling is based on a counting process. If so, it is merely a different aspect of a fallacy that we have already discussed. It may, however, be based on the use of such a restriction, for a very special reason, in one of Tippett's studies. In order to test independence of delay occurrences in a group of machines he needed to develop an empirical frequency table on the number of simultaneous delays to compare with a theoretical frequency table constructed on the hypothesis of independence. Tippett's application cannot, however, be taken as the basis for a general rule nor did he intend it as such. As a general rule it makes no more sense to require that a given delay occurrence be observed only once than it does to require that any particular period of productive activity be observed only once. If Tippett's application was in fact the source of this practice, responsibility for the fallacy rests upon those who endeavored to propagate the technique without understanding fundamental principles.

6. *As a general rule the number of observations should be such as to provide 95% assurance (2 sigma confidence interval) that the estimated percentage of time devoted to any particular class of activity is within ± 10% of the true percentage.* The only sensible basis for determining the required accuracy of an estimate is economic. The "optimum" sample size is defined by the point at which the cost of increasing the precision of the estimate by taking additional data is balanced by the returns gained from the improved precision. Such appraisals are rarely made in work sampling studies and that is why there is so much use of 2 sigma confidence levels and ±5% or ±10% as the desired precision of estimate. Such "standardized" objectives usually lead to uneconomic practice for the following reason.

The importance of an unproductive activity with respect to over-all efficiency of the operation is related to the amount of time spent on it. That is, a type of delay which consumes a great deal of time is in general more important than one which consumes little time. At the same time, we know from our error-of-estimate formulas, that in order to obtain the same precision of estimate, relatively, of a small percentage as we obtain on a larger percentage we will have to use a larger sample size.[2] That is, we spend more money to collect the data. Thus, adoption of a standardized precision requirement for work sampling studies leads us in the direction of spending the most effort on studying the least important classes of activity.

7. *If n rounds of observations are taken on a crew composed of k men and an observation is made on each of the k men in each of the n rounds, then the size of the*

[2] We will later show an exception in a special case of systematic sampling where the error of estimate is independent of the proportion.

sample to be used in calculating the error of estimate is nk. The correct statement is that the appropriate value for the sample size is a function of the degree of correlation between the activities of the crew members. The limits are nk in the case of complete independence (in which case we can scarcely speak of a "crew"), and n in the case of complete correlation. If, on observing one member of the crew one can predict from his activity the activity of one or more other members of the crew with probability greater than the per cent occurrence of that activity over-all, then there is some degree of dependence in the statistical sense.

Consider, for example, a football team. Suppose we were to make a work sampling study using the categories of activity "in play, huddle, time-out," with any transition activity being charged to the last of these categories in which the player was occupied. We would find perfect correlation and the sample size would be n, not nk, for in each round of observation we would obtain no more *information*[3] from observing k players than we could from observing one. Now, suppose we use a different categorization of the activities; say, "ball-handling, offensive blocking, passing, huddling, time-out, etc." Insofar as estimating the time spent in huddle, or time-out, is concerned, the problem would not be changed. We get zero information from all $k-1$ observations after the first in each round of observations. On the other hand, if we observed a tackle in offensive blocking we could not make a 100% assurance prediction on the quarterback. We could definitely predict, we hope, that he would *not* be taking time-out. And while we could not say whether he was ball-handling, passing, blocking, or immobilized under opposing tacklers we could predict any one of these with higher assurance than the average per cent of time spent in these activities. Thus, there is some reduction in information content of an observation.

An important point to note in this example is that there may be varying degrees of correlation among the various kinds of activities in which members of a crew may be engaged. However, if there is a high degree of correlation in any one class of activity, it automatically degrades the information content of observations on other classes of activities.

8. *In nearly all cases the occurrence of delays follows the binomial probability distribution.* There is no particular reason to expect that delay occurrences should follow a binomial distribution. And there are many instances where evidence shows that they don't. The reason for employing binomial probability theory is that errors of estimate will be binomially distributed providing the sampling is carried out in a certain way. In short, binomial probability theory is not thrust upon the Industrial Engineer through the nature of the problem, but comes into the matter through his own choice of the means employed to solve the problem.

This observation suggests that there may be other means equally or more effective than current work sampling techniques for solving the same types of problems. We need not limit ourselves to a requirement for random errors. There is a current tendency to consider estimating procedures "invalid" if they incorporate a biasing error The belief has no really practical foundation. The majority of measuring instruments used in industry today all have some bias in them. True, the bias must be trivial with respect to the purpose of the measurement; but this is exactly the point. A work sampling technique that permits a small biasing error may be preferable to one that generates larger random errors.

9. *For a given number of observations, random sampling will have a smaller error variance than any other kind of sampling.* About the best to be said for a completely randomized sample is that it *is* a way of getting the job done when one can't think of a better way to do it. In many cases there is a better way (1). Consider the simple modification of dividing the total study period up into time "cells" of say a couple of hours or a half-day each, and then assigning to each cell an equal number of observations to be randomized *within* the cell. In the terminology of market and census research this is "stratified-random" sampling. The variance of the sample proportion is:

$$\text{var } \bar{p} = \frac{\bar{p}\bar{q} - \text{var } p}{n},$$

where $\bar{p}$ is the mean value of p for all of the cells, and var p is the variance of p among cells. If p is actually a constant for all the cells within the study period, var $p = 0$, and the preceding equation reduces to the familiar variance equation for the binomial model. The thing to note, however, is that var p is always a negative term except when it is zero. Thus stratified-random sampling will never yield a greater variance than random sampling; and will always give a smaller variance whenever p is not constant over all situations.

It may help to visualize the principle if we go to a beads-in-bowl example. Suppose for this purpose that we have two bowls (i.e., two cells) and that (to bring out the principle) we take an extreme case where one bowl contains 100 black beads and the other 100 white beads. Now let us draw a sample of $n = 10$ first by completely random sampling, and then by stratified-random. The

[3] While this statement is intended in the "common-sense" notion of information it is also true in the information theoretic sense. Information is defined as a function of the change of probability of an event occurring attributable to receipt of a "message." Receipt of a message corresponds to making an observation. On observing player No. 1 in time-out the probability becomes 100% that the other $k-1$ players are also in time-out. On observing player No. 2 we find indeed that he is in time-out; that is, the probability after the "message" is 100%. But, it was 100% before the message so that message conveys no information. Obviously, it is not very efficient to transmit messages (i.e., make observations) that convey no information.

equivalent of random sampling in this instance would be to dump both bowls together, mix the beads thoroughly, and then draw our sample of 10 (with replacement, of course). The variance of the sample proportion will be $0.5^2/10=0.025$. In stratified-random sampling, on the other hand, we draw exactly 5 beads at random from each bowl (i.e., cell). The variance of the sample proportion will now be $(0.5^2-0.5^2)/10=0$. And we can convince ourselves that this is correct by simple logic. For in random sampling the composition of our samples could range over all combinations from 10 white beads to 10 black beads. But in stratified-random sampling we must always get exactly the same result: 5 blacks and 5 whites. And since every sample gives the same proportion, $\bar{p}=0.5$. The variance of this proportion is necessarily zero.

It is apparent therefore that as against random sampling, stratified-random will give no larger an error variance and in many instances a smaller one. There are two additional advantages. The first is that the observation schedules developed under stratified-random sampling are usually easier to meet than those generated by total randomization schemes. The second is that one can, at any time before completion of a stratified-random sampling program, increase the sample size merely by adding additional "cells," without changing the nature of the sampling design. The sampling density within cells remains the same; but the length of the sampling program must of course increase. The very nature of a completely randomized sampling scheme, on the other hand, prevents additions to the sample size after the study has begun because there is no way to "randomize" the additional observations over the *entire* study period.

Thus far in the remarks we have said nothing about the "statistical model" that gives rise to the variance equation for stratified-random sampling. Many statistical texts do not mention it at all. In Kendall's two-volume work on Advanced Statistics there is a discussion giving the first and second moments (3). We had occasion to employ the model in theoretical analysis of ground-to-air missile battles about five years ago and in connection with that work developed the third and fourth moments of the distribution in both exact and approximate forms. Unfortunately, the report of that study is not generally available, for it appears that this model may have other useful applications in Industrial Engineering.

10. *Randomization of the times of observation eliminates biases in the estimates of percent time spent in various activities.* People used to employ charms and magic incantations to drive away evil spirits. Nowadays there is a tendency to put the same kind of faith in randomization. Market research experts used sampling theory to control the probability of people being included in their samples, but found to their sorrow that statistics didn't necessarily make people say what they really wanted in an automobile. Similarly, in work sampling randomization may eliminate sampling bias, but it can't eliminate the kinds of bias that may occur when a worker is able to anticipate the making of an observation on his activity (e.g., by noting the approach of an observer, or by having it called to his attention). There need not be a consciously organized effort to bias study results. We have some evidence from psychological investigations that a man who knows he is about to be observed will unconsciously suppress tendencies to engage in a category of activity that he feels is less desirable than some other from the standpoint of the possible effects of study results on him. While biases of this sort are not necessarily large the chances of completely eliminating them are about the same as the likelihood that the Industrial Engineer making the study would write a completely unbiased job description on his own position.

Systematic short-interval sampling (such as by means of a 16 mm. camera set to take one frame every 30 or 60 seconds) should neutralize the effects of most unconscious bias and tend to discourage conscious bias by increasing the difficulty of accomplishing it. If it does not secure this result it may still produce enough information to permit an assessment of the bias. One should hold considerable reservations, however, on the advisability of pursuing a study by these means in the face of consciously contrived opposition.

11. *Randomization of observation times is necessary to satisfy the assumptions of statistical theory used to calculate a confidence interval.* This idea is subscribed to either explicitly or implicitly by a considerable number of writers on work sampling. Actually, the requirements of statistical theory are not nearly so specific. It will be sufficient if the error is a stochastic variable with a tractable distribution function. How we get the error to be this kind of variable is a matter of complete indifference to the statistical theory. We may attempt to do it by randomizing the observation times; but as we have just seen, this by no means guarantees the desired result. Indeed, it is entirely possible for systematic sampling to yield a "more random" error than "random" sampling.

To see why this may be so let's use the bowl-of-beads example once more. Let's suppose that there are 100 black beads and 400 white beads in the bowl and we are to draw a sample of five without replacement. Now the usual method of "random" sampling would be a thorough mixing followed by selection of the sample, without looking in the bowl. Presumably each of the 500 beads had the same chance of being the first in the sample, each of the 499 remaining beads had the same chance of being next in the sample, and so forth. But suppose that in fact some of the black beads had a slightly different texture from the other beads, a difference that did not impress itself clearly upon our consciousness but which nevertheless resulted in an unconscious discrimination. We would not in reality have a random sample.

Let's go about the sampling in a different manner. We

construct a long trough that will accommodate all of the 500 beads in a single long row. We decide arbitrarily that with all the beads lined up in this trough we will choose the 100th, 200th, 300th, 400th and 500th beads to constitute our sample. So we mix the beads up in the bowl and pour them into a single line in the trough. Now, each of the 500 beads has the same chance of being the 100th in this row, and each of the remaining has the same chance of being the 200th, and so forth. And so, with "systematic" sampling we end up with a random sampling error.

The important principle to be noted in this example is that systematic sampling of a population by position can provide random samples if the *occupancy* of those positions by members of the population is a random occurrence. Now let's try to extend this notion to systematic sampling of activities. Can we assume that different categories of activity occur randomly over time? It is extremely doubtful in most cases. For example, if we find an operator absent from his workplace on personal time at t_1, there is a fairly high probability that at $t_1 + \triangle t$ he will still be absent for the same reason; whereas if a few minutes later at t_2 he has returned to productive activity it is quite unlikely that he will be absent again on personal time at $t_2 + \triangle t$. Since we cannot find too much encouragement for assuming random occupancy of position in the macroscopic realm let us turn to the microscopic.

Suppose that we make the interval between our regularly spaced observations sufficiently small that whenever a particular category of activity occurs we will detect that occurrence in at least one observation. Or, let us at least make the interval small enough so that the exceptions to this condition are negligibly few for practical purposes. Now we will know that if a particular activity is identified in exactly five consecutive observations, the duration of that occurrence must have been greater than four times the interval between observations but less than six times the interval. Our uncertainty is due to the fact that we do not know the position of the beginning point of the activity occurrence in the interval between the last observation showing the preceding activity and the first observation showing the activity whose duration we are attempting to estimate; and to a similar lack of knowledge about the position of the end point. We can make a strong conjecture however that the probability of the beginning point being at any particular position on the interval is for all practical purposes the same for all positions on the interval; and likewise for the end point.

What we are proposing, in other words, is that the location of beginning and end points of activity occurrences is a stochastic variable uniformly distributed on the interval between observations. And no matter how nonrandom activities may be with respect to duration of occurrences, time of day at which they occur, or sequence of occurrence with respect to other activities, our error of estimate will be statistically "digestible" providing this one simple condition is fulfilled. The calculation of an estimate and confidence level under this condition are given by the following:

$p_A = \frac{n_A}{n}$; where p_A is an unbiased estimation of the true proportion of time, p_A, consumed in activity state A; n_A is the number of observations showing activity state A; and n is the total number of observations in the study. The error of estimate at p_A is normally distributed with zero mean and standard deviation $\frac{1}{n}\sqrt{\frac{N}{6}}$, where N is the number of separate occurrences of activity A during the study (i.e., the number of *sequences* of observation showing activity state A).[4]

SUMMARY

The work sampling technique has a surface appearance of exceeding simplicity. It is in a way like an axe. An amateur can pick it up and in spite of ineptitude produce some useful results if he puts enough labor in the effort. The skillful application will produce superior results with appreciably less effort, and with less likelihood of mishaps. However, we cannot expect to develop skill in anything without digging below its surface. The purpose of this discussion has been to mark some "digging places" where significant subtleties lie below the surface simplicity of work sampling.

[4] A more detailed discussion on the problem of sampling error estimation in systematic sampling is given in (2).

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Monopologs: Management Decision Making Game Applied to Tool Room Management

by **FORREST M. CAMPBELL** *and* **E. ROBERT ASHWORTH**

School of Industrial Engineering and Management, Oklahoma State University

FOR SEVERAL years the Logistic department of the RAND corporation has been concerned with the various supply problems of the Air Force. Mathematical models have been used to represent various parts of the supply system. H. W. Karr developed a model for part of the supply system of the Air Force (2). He focused his attention on the operation of the base-depot phase of the system. He was concerned with the present policies and their improvement. W. Hamburger concentrated his attention on a less elaborate model of the base-depot part of the system (1). His goal was to become better acquainted with the interworkings of the system rather than the finding of new policies. Monopologs is a compound name composed of "Monopoly" and "Logistics."

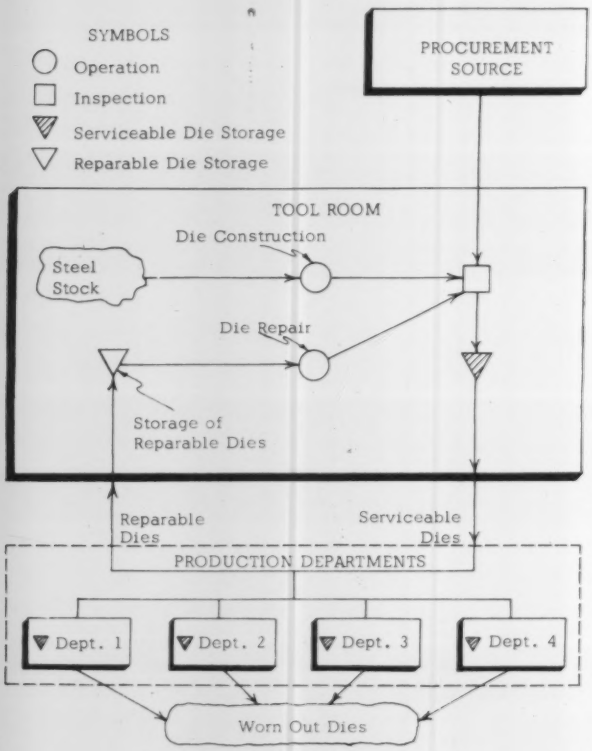

FIG. 1. Flow Diagram for Dies.

It is an informative game that attempts to relate the gross factors with which a management would be concerned in the analysis of the high value of spare parts. The game includes the procurement, repair and shipment of spare parts to five bases in a hypothetical supply system. J. Rehkop describes some of the experiences of playing this type of game (3).

A PEDAGOGICAL APPLICATION OF MONOPOLOGS

One of the pedagogic problems which confronts all who teach is the task of motivating the student. This basic problem is encountered whether the setting is academic or industrial. From the many different business games now in existence, one of the significant factors as a result of playing the game is the tremendous motivation which the game imparts to its players. The purposed tool room game will motivate the student to ask why he makes the decisions he does, what the effect of certain policies will have, and how well they meet the given situation.

The students are given a complete write-up of the tool room game to review and study before the next class period. The student's questions are answered if there are any over the previous written material which covers the sample game.

The students are asked to formulate a set of policies for themselves and to apply them to the game to be played in the classroom. At the end of play, the student will be asked to discuss how his policy was applied, and the cost of this policy for this game will be determined The objective is to achieve the "best" results (any number of criteria might be used) with a minimum of cost or a maximum of profit. Generally, the individual with the lowest cost will be considered to be the best manager.

GENERAL SETTING

The setting for this game of Monopologs is shown graphically by Figure 1. (The player should become thoroughly familiar with Figure 1.) The players assume the role of the tool room manager whose responsibility it is to see that the four production departments within a factory are adequately supplied with a particular type of die. (The specific type is not important.) The objective of the game is to supply these production departments with a sufficient number of dies so that they can

TABLE 1
Lead Times

Die Construction Lead Time	5 Weeks
Die Procurement Lead Time	9 Weeks
Expedited Die Procurement Lead Time	3 Weeks
Die Repair Lead Time	3 Weeks
Expedited Die Repair Lead Time	1 Week

maintain their production schedules and at the same time you, as tool room manager, can keep die storage, transportation and manufacturing costs at a minimum. Each department generates two kinds of demands for the spare dies: wearouts and reparables. To meet this demand, new dies may be procured from a manufacturer, new dies may be constructed in the tool room, or reparable dies may be repaired in the tool room. It is up to the tool room manager to determine which method will be used to meet the various demands which arise due to random causes during a 30 week period.

PROCUREMENT COSTS AND LEAD TIMES

The cost of procuring a new die from a manufacturer is \$50.00 per die. For every order (regardless of size) there is a setup cost of \$50.00 per order. If the procurement is routine, it takes nine weeks for the die to reach the tool room storage from the initiation of the order. It is possible to expedite procurement at an additional cost of \$100.00 per order and the lead time is reduced to three weeks. It is possible to expedite an order at the time it is placed, or at any time before the shipment arrives at the tool room. In all cases the expedited items will arrive at the tool room three weeks after the order to expedite is given.

Example: Routine procurement of 4 dies: Cost = 50 + 4(50) = \$250 (9 weeks).

Example: Expedited procurement of 4 dies: Cost = 50 + 100 + 4(50) = \$350 (3 weeks).

Note: In order to receive maximum benefit from the game and keep the game interesting, any procurement of new dies is not to exceed 10 per week. A further restriction on procurement is that after the initial procurement is made (during the first week), no further procurements are allowed until the eleventh week.

CONSTRUCTION COSTS AND LEAD TIMES

The cost of constructing a new die in your own tool room is \$40.00 per die. For every order (regardless of size) there is a tool room set-up cost of \$115.00 per order. It is assumed that this tool room has many other tools and fixtures going through it simultaneously. For this reason a limitation has been placed on the number of dies that can be constructed simultaneously. The maximum number of dies that can be constructed in the tool room is four. Five weeks elapse from the time the order is placed until it reaches the tool room storage. There is no way to expedite construction orders going through the tool room.

Example: Construct four dies in the tool room (maximum number). Cost = 115 + 4(40) = \$275 (5 weeks).

REPAIR COSTS AND LEAD TIMES

The cost of repairing a reparable die is \$20.00 per die. For every order (regardless of size) there is a set-up cost of \$20.00 per order. If the repair is routine, it takes three weeks from the time the order is placed until it arrives at the tool room storage as a serviceable die. It is possible to expedite repair for an additional cost of \$40.00 per order. There is no limit to the number of reparable dies passing through the shop for repair. An order may be expedited at the time it is placed or at any time thereafter, with delivery to the tool room storage one week after it is expedited.

Example: Routine repair of 4 dies: Cost = 20 + 4(20) = \$100 (3 weeks).

Example: Expedite repair of 4 dies: Cost = 20 + 40 + 4(20) = \$140 (1 week).

OTHER COSTS AND LEAD TIMES

TRANSPORTATION

Serviceable dies can be shipped from the tool room storage to department or from department to department. There is no charge for transportation from the tool room storage to department. (This cost is included in procurement, construction, or repair costs.) However, there is a charge of \$5.00 per shipment for transportation from department to department. In both cases the transportation time is one week.

DEPLETION PENALTY

This cost (\$200/Die/Week) is charged if a spare die is not on hand in a department at the time a demand is generated there. Of course, this is charged each week there is a shortage.

STORAGE

There is a storage cost of \$1.50 per die per week for reparable dies on hand. There is also a storage cost of \$2.50 per die per week for each serviceable die in the tool room storage and for all spare dies in the four departments. Figure 2 illustrates a comparison of the costs of the different activities with respect to the number of dies.

DEMAND GENERATION

Dies have to be replaced within the production departments for two reasons—some of them wear out and are discarded; others become reparable.

A reparable or wearout demand is equally likely to occur in any department in any week. The demand is erratic due to the fact that these demands arise due to random causes.

The rate at which the demands occur is not known.

TABLE 2

Special and Routine Charges

Special Charges	
Procurement Set-Up Cost	$ 50/Order
Expedited Procurement Order Cost	100/Order
Construction Set-Up Cost	115/Order
Repair Set-Up Cost	20/Order
Expedited Repair Order Cost	40/Order
Department to Department Transportation Cost	5/Shipment
Depletion Costs	200/Die/Week
Routine Charges	
Procurement Cost	$ 50/Die
Construction Cost	40/Die
Repair Cost	20/Die
Serviceable Storage Cost	2.50/Die/Week
Reparable Storage Cost	1.50/Die/Week

However, examination of past data for one department operating under similar conditions showed that two reparable and four wearouts, a total of six demands, occurred during a ten-week period. (As the game progresses a more refined estimate of the two demands will become available.)

In Figure 3 we have a typical distribution of six demands in a ten-week period. If we tabulate our past data from the shop we might have a distribution of events as shown in the top distribution. From this Poisson distribution with a mean of 0.59 or 0.6 we can then determine the cumulative frequency of occurrence of our demands. Assigning a series of two digit random numbers to the cumulative distribution we have a distribution of numbers which is unbiased and not affected by our tendencies toward favorite numbers.

To generate a series of events we can glance at the second hand on a watch and if the number of seconds is more than 50, we wait a bit and select a second number. If we have 50 or less seconds, we double the number. If our original number were odd, we would subtract from the total. Two digit random numbers can be determined without a table of numbers.

In another method, called the mid-square method, we select a four-digit number, then square the number and use only the middle four digits. This number is the next random number. The process is repeated until all numbers have been determined.

One also might write the digit 0 on 55 chips, 1 on 33 chips, 2 on 10 chips, and 3 on 2 chips. Mix the chips in a bowl and select the chips one at a time. After reading the number from the chip, replace it in the bowl, stir well and repeat the process.

THE PROGRAM

The time span is 30 weeks. At the end of 30 weeks the dies will have no further use and will be considered obsolete. The player will receive no credit for either serviceable or reparable units on hand at the end of the 30 week period.

Four departments will be using the dies during this period. They will become active according to the schedule below and will remain active until the end of the game.

Department 1	Becomes Active in Week 11
Department 2	Becomes Active in Week 15
Department 3	Becomes Active in Week 18
Department 4	Becomes Active in Week 24

The same number of presses will be operating in each department. Each press has been initially supplied with a proper die, therefore, these do *not* need to be supplied from the tool room storage when the department becomes active.

From a table of random numbers we might write down the following numbers: 28, 52, 76, 48, 71 99, . . . Interpreting these reparable and wearout demands we would have these results:

Reparables	Wearouts
0	0
1	0
1	3
.	.
.	.

DESCRIPTION OF THE PLAYING FIELD (See Figure 4).

PROGRAM (COLUMNS 1, 2, 3)

This information is known to the player at the start of the game. These columns are self explanatory—column 1 is the week number, column 2 shows when each department becomes active and column 3 is the total number of department weeks.

TOOL ROOM STORAGE SUMMARY

Column 4: This indicates the number of serviceable

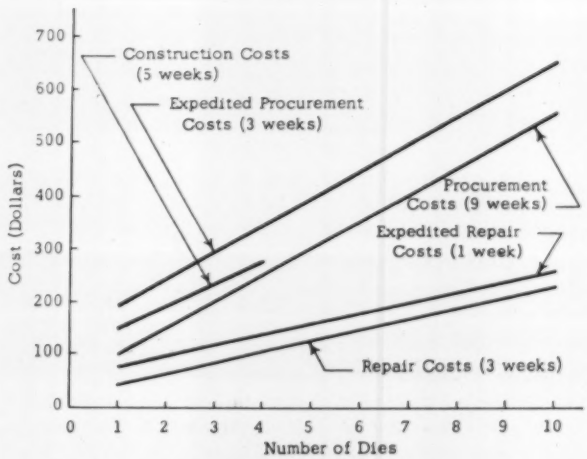

FIG. 2. Comparison of Costs.

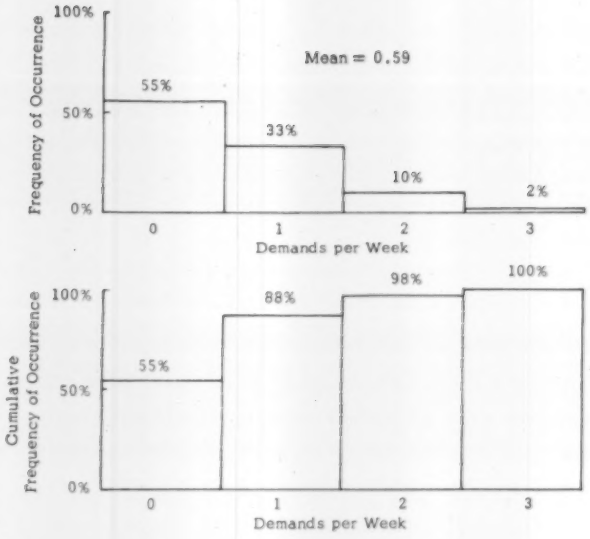

FIG. 3

dies on hand in the tool room at the beginning of the week. This is the same as the number of dies on hand at the end of the previous week which is found in column 7.

Column 5: In this column is recorded:

1. Procurement orders—example *p*4.
2. Procurement expedite orders—example *pe*4.
3. Construction orders—*c*4.
4. Arrival of serviceable dies from the procurement source, tool room construction, or tool room repair—example 4.

Column 6: Denotes that a delivery will be made from tool room storage to one of the departments—example 4 to D_1 (4 serviceable dies will be delivered to Department 1).

Column 7: In this column is found the serviceable dies on hand in the tool room storage at the end of the week. This number is equal to B (column 4) + A (column 5) − D (column 6) = ∇ (column 7).

TOOL ROOM ACTIVITIES

Column 8: This column indicates the number of dies that are being repaired during the week. Example: The player decides to repair 4 dies in a certain week. He records the number 4 in column 8 for the following 3 weeks.

Column 9: As reparable dies accumulate they are recorded in this column. When the player wishes to repair them he records R or Re beside the number of reparable dies.

Column 10: This column indicates the number of dies that are being constructed in the tool room during a particular month. The largest number of dies that can be constructed at one time is 4.

DEMAND SUMMARY

Column 11: Denotes the total number of demands, both reparables and wearouts, that have occurred to date. It is the sum of columns 12 and 13 for the particular week.

Column 12: Information for this column comes from the demand for reparables as they occur in columns 14-17. These data are kept in the form of a summation of all the reparables that have occurred to date.

Column 13: Same as column 12 except these data concern wearouts only.

DEPARTMENTS

Columns 14-17: The demands shown in columns 14-17 are covered at the beginning of the game so this information is unknown to the player. The demands are uncovered week by week as the play progresses.

DIES SERVICEABLE

Column 18: This column shows the total number of serviceable dies in the system at the end of the week. This total is equal to B (column 4) + A (column 5) + (the number of serviceable dies on hand at the end of the week in each department) (columns 14-17) = S.

PROCEDURE OF THE GAME

Play progresses in the following general manner:

1. *Events* are generated by uncovering the demand data in columns 14-17. (See Figure 4.) After uncovering these data, record any deliveries to departments that were sent from the tool room or from other departments the previous week. Then, for each department, considering its inventory, demands for the week, and newly arrived items, determine and record the inventory of serviceable dies.
2. Bring demand summary up to date (columns 11-13). Also record the number of dies reparable (column 9).
3. *Take inventory*. This covers the dies on hand at the beginning of the week (column 4) plus the arrvials (column 5) plus the inventory in each department (columns 14-17).

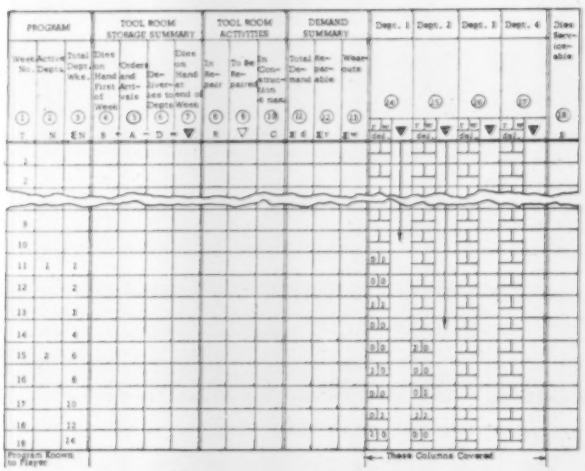

FIG. 4. Example Game—Playing Field before Game Begins.

TABLE 3

Score Sheet	Number	Cost
1. Procurement Set-Up (50/Order)		
2. Procurement Expedite Order (100/Order)		
3. Procurement Each Item (50/Item)		
4. Construction Set-Up (115/Order)		
5. Construction Each Item (40/Item)		
6. Repair Set-Up (20/Order)		
7. Repair Expedite Order (40/Order)		
8. Repair Each Item (20/Item)		
9. Department to Department Shipments (5/Shipment)		
10. Depletion (200/Item/Week)		
11. Reparable Storage (1.50/Item/Week		
12. Serviceable Storage (2.50/Item/Week)		
Total Cost		

4. *Make decisions* and record them. Decisions will be recorded in columns 5, 6, 8, 10, 14-17.

5. With all the information properly tabulated on the playing field for that week, then uncover the demand data for the next week and repeat the procedure.

SCORING THE GAME (See Table 3.)

The score of the game is not counted until the game has been completed. Below is the procedure for scoring the game:

1. *Procurement set-up*—Count all the letters *p* which appear in column 5. Multiply this number by $50.00.

2. *Procurement expedite order*—Count all of the *e*'s which appear beside *p*'s in column 5. Multiply this sum by $100.00.

3. *Procurement each item*—Find the sum of all the dies obtained by procurement (column 5) and multiply this sum by $50.00.

4. *Construction set-up*—Count up all the letters *c* which appear in column 5 and multiply this sum by $115.00.

5. *Construction each item*—Find the total number of dies constructed in the tool room (column 5) and multiply this number by $40.00.

6. *Repair set-up*—Count the number of *R*'s which appear in column 9 and multiply by $20.00.

7. *Repair expedite order*—Count the number of *e*'s which appear beside *R*'s (column 9) and multiply this number by $40.00.

8. *Repair each item*—Find the sum of all the dies repaired (from column 9) and multiply by $20.00.

9. *Department to department shipments*—Check columns 14-17 to see how many department to department shipments occurred during the game. Multiply the number of shipments by $5.00.

10. Check columns 14-17 to see if any minus numbers appear in the inventory columns for the departments. Add these depletions and multiply by $200.00.

11. *Reparable storage*—Find the sum of all the numbers in column 9 and multiply by $1.50.

12. *Serviceable storage*—Find the sum of all the numbers in column 7 plus the sum of the positive numbers appearing on the inventory side of columns 14-17. Multiply this total by $2.50.

EXAMPLE GAME (See Figures 5 and 6.)

MONTH BY MONTH SUMMARY OF EVENTS AND DECISIONS

The following game illustrates all possible decisions that can be made and the resulting costs that arise. This game should be studied merely as a guide to properly tabulate information. *This example game should not be used as a decision making guide!*

Start of Play: This corresponds to week 1 and is the time when initial procurement order of dies is placed.

Decision: Make a routine procurement of 4 dies. Record *p*4 in column 5 for week 1 (order). Record 4 in column 5 for week 10 (arrival).

10th Week:

Events: None.

Inventory: 4 Serviceable dies. (column 5)

Decision: Construct 4 dies in our tool room. Record *c*4 in column 5. Record 4's in column 10 for 11-15th week. Record 4 in column 5 for 15th week. Send 2 dies to Department 1. Record (2 to D_1) in column 6.

11th Week:

Events: D_1 becomes active. 1 wearout in D_1. 2 dies delivered to D_1 from tool room.

Inventory: 2 (column 4) + 1 (column 14) = 3 serviceable dies.

Decision: Deliver 2 dies to D_1. Record in column 6.

12th Week:

Events: 2 deliveries to D_1 from tool room.

Inventory: 3 (column 14) = 3 serviceable dies.

Decision: None.

13th Week:

Events: 1 reparable and 1 wearout at D_1.

Inventory: 1 serviceable die (column 14).

Decision: Place repair order expedited on the one reparable die. Record *Re* in column 9. Record 1 in column 5 for week 14. Record 1 in column 8 for week 14.

14th Week:

Events: None.

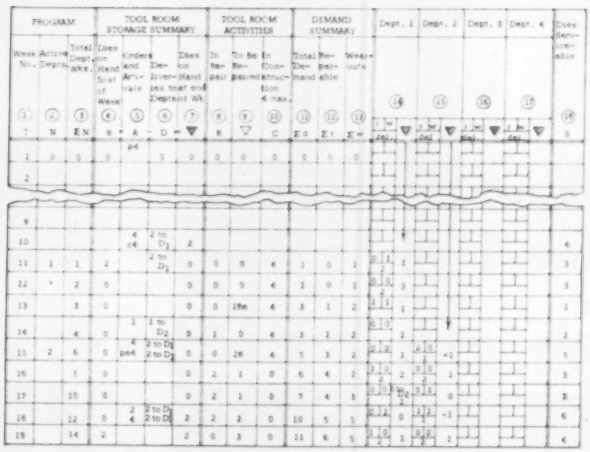

FIG. 5. Example Game—Playing Field after Game Completed.

Score Sheet	Number	Cost
1. Procurement Set-Up (50/Order)	2 Orders	$ 100.00
2. Procurement Expedite Order (100/Order)	1 Exp.	100.00
3. Procurement Each Item (50/Item)	8 Items	400.00
4. Construction Set-Up (115/Order)	1 Order	115.00
5. Construction Each Item (40/Item)	4 Items	160.00
6. Repair Set-Up (20/Order)	2 Orders	40.00
7. Repair Expedite Order (40/Order)	1 Exp.	40.00
8. Repair Each Item (20/Item)	3 Items	60.00
9. Department to Department Shipments (5/Shipment)	1 Shipment	5.00
10. Depletion (200/Item/Week)	2 Dep.	400.00
11. Reparable Storage (1.50/Item/Week)	10	15.00
12. Serviceable Storage (2.50/Item/Week)	19	47.50
Total Cost		$1482.50

FIG. 6. Example Game—Tabulation of Score.

Inventory: 1 (column 5) + 1 (column 14) = 2 serviceable dies.

Decision: Deliver 1 die to D_2.

15th Week:

Events: 2 reparables generated at D_2. 1 delivery to D_2 from tool room.

Inventory: 4 (column 5) + 1 (column 14) = 5 serviceable dies.

Decision: Deliver 2 dies to D_1. Deliver 2 dies to D_2. Expedited procurement of 4 dies. Record *pe*4 in column 5 for week 15. Record 4 in column 5 for week 18. Repair the two dies reparable. Place *R* by the 2 in column 9 for week 15. Record 2 in column 5 for week 18. Record 2 in column 8 for weeks 16-18.

16th Week:

Events: 1 reparable die generated at D_1. 2 dies delivered to D_1 from tool room.

Inventory: 2 (column 14) + 1 (column 15) = 3 serviceable dies.

Decision: None.

17th Week:

Events: 1 wearout generated at D_2.

Inventory: 2 (column 14) = 2 serviceable dies.

Decision: Deliver one of the serviceable dies at D_1 to D_2. Record delivery in column 14.

18th Week:

Events: 1 wearout generated at D_1. 1 reparable and 1 wearout generated at D_2. Delivery of one die to D_2 from D_1.

Inventory: 6 (column 5) = 6 serviceable dies.

Decision: Deliver 2 dies to D_1. Deliver 2 dies to D_2.

19th Week:

Events: 1 reparable generated at D_1. Delivery of 2 dies to D_1 from tool room. Delivery of 2 dies to D_2 from tool room.

Inventory: 2 (column 4) + 1 (column 14) + 1 (column 15) = 4 serviceable dies.

No decision—end of game.

SUMMARY

A small scale decision making game has been applied to the classroom without the use of an electronic computer. The game is intended to focus attention on only a very limited area of an operational situation. The umpire of the game should be aware of the players' motivation. In the discussion which follows the game he should point out the strengths and weaknesses of the policies employed. The student should be encouraged to employ a questioning attitude on his own policies. Extensions of this type of game are limited only by one's imagination and the degree of complexity one wishes to employ.

Higher level games could be composed of a series of simpler games, which are blended into one game encompassing the broader aspects of the manufacturing enterprise.

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The Reorganization Controversy

by **HOWARD UROW**

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JUST as there arose in the literature numerous philosophies and concepts of industrial organization, many authorities from various fields soon began to express divergent views on how exactly to effect the new organization plan, and whether, in fact, it was even desirable to alter the present organization structure under any circumstances. The proponents of the latter view hesitate to suggest reorganization basically because of the inherent risks involved in successfully bringing about change where people are concerned.

This feeling is held quite strongly by those management people who refuse to alter their industrial organizations in face of the need for reorganization and the recommendations of consultants and lower management personnel. The resistance of influential executives to reorganization is particularly difficult to overcome when the need is not obvious or urgent. For example, the General Motors organization concept of "decentralized operations with centralized control" took over 25 years to gain wide acceptance among other companies with similar operating characteristics (3, p. 174).

This article will explore this general issue of whether or not reorganization is desirable when the need for it is found to exist. The issue of reorganization only arises when the need for the change arises, so the first study in this effort will be devoted to identifying the circumstances under which reorganization is needed or often suggested as an effective corrective action. In effect this becomes the argument for reorganization. Next the problems involved in and arguments against reorganization will be examined. Finally a conclusion will be reached either in favor of or against reorganization, and the various approaches to reorganization will be considered.

The controversy between the proponents of reorganization and the skeptics is severest when the need for reorganization is subtle. When reorganization is necessary for the immediate survival of the enterprise, and this is obvious to management, there is little quarrel over whether or not to reorganize. The only question is how to achieve reorganization. However when reorganization is suggested to improve a company's relative competitive position or it is argued that reorganization is necessary to keep abreast of the field, the advisability of reorganizing is not so evident.

THE CONCEPT OF REORGANIZATION

Any definition of reorganization necessarily depends upon a definition of industrial organization. Dale defines organization planning as "the process of defining and grouping the activities of the enterprise so that they may be most logically assigned and effectively executed . . . to further the objectives of the enterprise" (3, p. 16). The emphasis here is on a dynamic planning process which must continuously operate from day to day as a means to achieving the company's objectives. The significance of this dynamic aspect of organization planning will take on deeper meaning as one philosophy of reorganization is examined more closely.

The activity of organizing, then, is the planning that sets up, develops, and maintains an organization structure. The activity of reorganizing is the planning process that changes the organization structure (i.e. the procedures and pattern of working relationships). The structure is static and is a product of the planning which is dynamic. In effect, reorganization is part of true organization planning; because to be dynamic, organization planning must adapt and change the structure that it creates.

Reorganization may involve a change in the procedures and working relationships and not in the personnel, a change in the personnel with the same basic structure, or a change in both. Reorganizing the personnel may consist of shuffling about the present executives and department heads, the introduction of a single new chief executive, or the introduction of a number of new members of middle management.

GRADUAL NEED ARISING FOR REORGANIZATION

The need for reorganization may arise rather suddenly or slowly over a number of years. Some of the strong arguments for reorganization rest on the belief that only a new organization can remove the maladies of the old one.

Drucker cites four symptoms of malorganization which gradually creep into the organization structure and for which he suggests reorganization as the fundamental remedy (6, pp. 224-226). The first is *a growth in the number of levels of management.* Too many levels in the organization may signify poor or confused objectives or the failure on the part of top management to remove from the organization structure positions and personnel no longer serving any purpose. Perhaps management added new personnel and new positions to undertake responsibilities which really should have been handled by other members of the organization.

Rather than in a growth in the number of levels, this same practice can manifest itself in *a growth in the number of assistants to, expediters, coordinators, and*

committee meetings. The presence of such overhead is a second symptom of malorganization. Weak communications sometimes also account for the creation of these jobs and for a good many committee meetings.

A third symptom is *the tendency to have to go through channels rather than to deal directly with the man in the organization who has the needed information or ideas*. This is a sign of the informal organization trying to arise to correct the deficiencies of the formal organization. The purpose of reorganization here would be to incorporate the informal organization into the formal. However this should not be mistaken to imply that all aspects of the informal organization should be reorganized into the formal—only that part of the informal organization which is prevented from correcting the deficiencies of the formal by the restrictions imposed upon it by the formal organization.

Certain informal practices can better attain the organization's objectives if they remain informal than if they are incorporated into the formal organization. This is because of some people's aversion to formal procedures and the importance of a confidential personal contact. An organization chart would be impossible to read if it attempted to account for all the purposeful direct contacts made between members of the organization. The presence of these informal practices which correct the formal organization's deficiencies should not be construed as a sign of the need for reorganization. However the tendency to have to go through channels is a sign that the effectiveness of informal procedures is being curtailed by the requirements of the formal organization, and that reorganization is needed.

The fourth symptom of malorganization which Drucker sees gradually arising in many organizations is an *unbalanced management age structure*. If the average age of the men in the responsible positions is below 40, good men will not join the organization and many of the younger will not find ample promotional opportunities. Also there is a lack of mature experience. On the other hand if the average age is over 55, not enough men are around to step in when the older men retire; the continuity of the organization suffers. In either case Drucker favors creating new jobs and finding new men in order to balance the age structure.

Often the organization defects which slowly arise creating the need for reorganization are the result of significant growth or decline in the volume of business activity for the firm. *Growth and decline are the cause of a multitude of malorganization symptoms:* slowness or errors in decision making, excessive span of control, "too many chiefs and not enough Indians," staff-line conflicts, improper division and delegation of work, lack of uniformity in policies, narrow outlook of management, personal objectives of department heads out of line with objectives of the company, high turnover or sickness among executives, failures to meet delivery schedules, bottlenecks in production, and personality clashes. The proponents of reorganization argue that all of these are signs of a defective organization and can only be corrected by getting at the heart of the matter through a complete overhaul of the organization.

SUDDEN NEED ARISING FOR REORGANIZATION

There are also certain circumstances which almost overnight create a need for reorganization. Dale claims that the most frequent reason for reorganizing the company structure is a change of top executives (3, pp. 173-174). The new executives themselves may be part of the reorganization planning or their appearances may be precipitated by a retirement or death. In either case different executives have their own personal philosophies on organization and probably function best under that type of organization.

The acquisition or sale of properties, plants, or companies may create the need for reorganization on short notice. The details of the transaction generally preoccupy the participants' time to the exclusion of any consideration for the details of the organization which will have to be developed afterwards in order to best satisfy the objectives of the transaction.

Unexpected shifts in the economic fortunes of a business enterprise can also quickly create the need for reorganization. The shifts may be due to general business conditions, competitors' actions, or the industry's cyclical fluctuations. Generally as business conditions worsen, the reorganization is made to give top management greater control and as business conditions improve, the reorganization proceeds along lines of decentralization of authority and control.

Two final situations in which the need for reorganization is created in a short period of time are the introduction of a new product or a technological breakthrough, and a legal decision compelling financial reorganization. Financial reorganization may also be voluntary if the fortunes of a firm decline beyond the point where ordinary business strategy permits recovery.

THE VALUE OF CHANGE IN OUR CULTURE

So far the arguments for reorganization have been extracted out of the economic environment of the American business firm with pressures for change exerted by its personnel and financial resources, and by its competition. However the cultural environment also exerts a pressure for change that can't be overlooked. Ginzberg and Reilley point out that in the United States change itself is valued (7, pp. 18-19). As a people we believe in progress and are willing to put forth continuing effort in that direction. Although this model may not apply to the average working man, it more accurately describes the modern business leader who is in a position to introduce change. Also business administrators are becoming more and more professionalized and are acquiring a deeper un-

derstanding about the ways in which large organizations can more effectively operate. They are becoming more aware of the principles and latest developments in scientific management and are more anxious than ever to bring their organizations up-to-date. The modern business practitioner is as dynamic as the society in which he lives and desires to run his enterprise accordingly.

One may ask then why there are any administrators against reorganization. Perhaps these are the men in management who have not become professionalized, who have not been exposed to scientific management, and who have not received the formal business education that has developed an organization philosophy favoring change in so many of the business leaders of today.

The need for this professionalization of management is not so imperative in smaller firms as it is in larger corporations—hence, the prevalence of those administrators who are opposed to reorganization in smaller firms. Also, management has a memory. They may have gone through some bad experiences previously with reorganization attempts and are fearful of trying again. It is a paradox that the smaller firms which generally are most in need of reorganization are the easiest for which to draw up sound organization plans but are the most difficult industrial organizations in which to actually achieve successful reorganization.

CAUTIONS AGAINST REORGANIZING

Although as noted some pressures for reorganizing are strong, top management is often inhibited from initiating major departures from customary procedures and the old tested organization. Many managements will think long and hard before introducing changes which, whatever their long-run value, tend to unsettle established relations among the individuals and groups which have already proven their worth by making a success of the enterprise. Here management is thinking of the reorganization proposed for improving the company's relative position in the industry and not of the proposal which arose out of the need to maintain its position or to survive.

The principal arguments against reorganizing consist of a series of cautions to be observed in undergoing the reorganization. No basic opposition to the general philosophy can be found anywhere in the literature. The cautions essentially center around meeting the human problem of resistance to change. People prefer to stay with the work they know rather than to take on a new unknown assignment; to remain with the supervisor for whom they have learned to work rather than to be assigned to a new one who might be easier but who could also be more difficult to live with than the other.

Bavelas, a social psychologist, refers to the social framework that develops in an organization (2, p. 48). Within this framework all the personnel know what is proper behavior and what is not. This culture becomes comforting to the individuals in the organization because they can act automatically without serious thought. In a new organization behavior has to be tested all over again. The personnel lose their sense of direction and feeling of security during reorganization. By upsetting the social framework, a good deal of anxiety and tension are created often at the expense of the full acceptance of the reorganization plan. The risk that is thus incurred often adds meaning to the proverb, "Let sleeping dogs lie."

Often the new plan appears to be accepted, when in truth these are only surface appearances. This is dangerously misleading and must be cautioned against. The adaptation which appears to be taking place may be forced at a terrific price to the people involved if they have any internal tensions and uncertainty about how the change will personally affect them. Some employees may have fears about the usefulness of their present experience with the company after the reorganization in spite of previous reassurances from management. *One authority in personnel and industrial relations even traced heart trouble, ulcers, and nervous breakdowns to these tensions created during a reorganization* (12).

Another caution commonly expressed is against losing through the reorganization process any of the status symbols which the employees have come to rely upon. But no matter what form the reorganization assumes or how well it is planned or how well management prepares the personnel, someone is bound to feel a loss of position and status. Visions of demotion are common; unavoidable demotions are sometimes even part of the reorganization plan. When reorganization is undergone to decentralize authority, a common result interpreted to mean a loss of status by the employee is the requirement that he report to a new boss further down the chain of command (11, pp. 149-155).

THE OBSTACLES OF QUALIFIED PERSONNEL AND TOP MANAGEMENT SUPPORT

Ginzberg and Reilley argue that reorganization is destined to fail unless new and qualified personnel are introduced into the organization (7, pp. 29-37). Their philosophy, which is about as opposed to reorganization as can be found anywhere, rests on the strong premise that any reorganization, to be successful, ultimately depends upon the performance of the personnel in the new assignments. Thus before ever deciding to go ahead with reorganization, management must cautiously review its personnel resources and try to evaluate employees' performances under the new and untried conditions. Such an evaluation is undoubtedly very difficult. Then the question arises that if management decides the qualified personnel are available in the old organization to operate effectively under the new organization, why couldn't these people make the old organization work?

This line of reasoning follows from identifying the personnel in the organization with organization itself.

Ginzberg and Reilley argue that because the organization is really the people in it, any change in their working relations and not in the personnel is actually not a change in the organization. Finally if the personnel could not operate the old organization effectively, there is no reason to believe they could run the new one with any better results.

A contradictory point of view is taken by Dimock. He concedes that bureaucracy, the rules, regulations, and formal procedures too often receive all the attention in reorganization; and that the employees and company goals tend to be neglected as a consequence (4, pp. 159-166, 246-255). However he finds that the same personnel can successfully be reorganized if properly and patiently reorientated under the new rules and procedures. All that is necessary for the reorganization to be a success without the introduction of new personnel is that they be given a chance "to settle into a groove."

These conflicting views can be reconciled by noting wherein each source places responsibility for the organization's success. Ginzberg and Reilley rely more on the employees themselves. Dimock places more faith in the ability of the executive to control and direct the organization. For example, Dimock would maintain that the only reason why qualified employees were not able to function effectively under the old organization was because they were not free to alter the nature of their jobs and their interrelationships. Dimock looks upon the organization as a "network of executive control," and reasons that unless that control allows the organization structure to adapt to changing conditions, the old organization as well as any new one is doomed.

To place complete responsibility for the success of the reorganization in the hands of the employees is to admit to weak executive control. Reorganization in this situation without a change in the behavior of top management has little chance of succeeding. Such reorganizing is often attempted through the services of an organization expert, who for the sake of expediency follows the course of least resistance—appeasing the employees. He seldom takes the time to learn the fundamentals of the company's organization problems. He may fail to understand the more subtle personal considerations within the organization. Needless to say the reorganizer is a very unpopular fellow who meets with a lot of resistance which makes his job all the more difficult. Under these circumstances it is true that a change in the forms, practices, and procedures with the same personnel and with top management unchanged is a poor basis for reorganizing. Indeed the only hope for this organization structure is new employees and new managers.

Dimock states that organization analysis "is the continuous responsibility of the executive" and not "the periodic pursuit of the expert." When the executive reorganizes, he accepts a change in his behavior, in his control, and in his responsibility. When he is told to reorganize, to delegate more responsibility, to do more thinking and less doing, he may find it impossible to change the habits of a lifetime. Without this change in attitude the reorganization plan is under a severe handicap.

CONCLUSION ON DESIRABILITY OF REORGANIZATION

Reorganizing to improve the company's relative competitive position, to maintain it, or to survive are all as vital to the successful and continuous operation of an industrial organization as new and improved products, promising fresh executive leadership, and more economical methods of manufacturing. To oppose reorganization because of the risks involved is a sure sign of incompetent and unconfident management.

PHILOSOPHIES ON THE APPROACH TO REORGANIZATION

Just as different views were found on the desirability of reorganiaztion, so are there different philosophies on the approaches to take in order to achieve successful reorganization. Each philosophy on how to reorganize must be considered in light of the arguments raised against reorganizing. These cautions, as discussed, highlight the problems which must be overcome in initiating a reorganization plan.

There are two extreme philosophies on the approach to reorganization (3, pp. 185-187). The first, unfortunately, is the most commonly practiced one. It is one of expediency and is termed the "Earthquake Approach." It calls for announcing and effecting the change almost simultaneously. It is generally undertaken by companies unfamiliar with the principles of reorganization and by companies which find reorganization to be a one-time change. Under it all the fears of the social psychologists and of the conservative practitioners are realized. Morale is injured; harmonious relationships are prevented from ever fully developing; and the reorganization plan's success is seriously hampered.

At the other extreme is the second philosophy, the long-run "gradualist" or *perpetual reorganization approach*. Under this philosophy the company is perpetually reviewing its organization. Major changes are gradually introduced over a period of years; minor changes are *always* being introduced. Organization change is a never-ending process just as the business environment is constantly changing in one way or another. Employees are given enough time to adapt themselves to the new procedures and bosses. The personnel, in fact, become accustomed to gradual change and expect adjustments to be made in the organization structure continuously. Their cooperation is assured. Top management here is alert and is always looking ahead to the changes which will be needed in the future in order to plan for them in the present.

In between these extremes are philosophies which are designed to initiate reorganization without hampering the

social framework (2, p. 50). One which is very close to the perpetual philosophy but which does without the constant review and continuous change is termed the *accommodation approach*. This approach calls for first getting the employees used to the need for a change, then the consideration of changes, the change decided upon, the trial run of the change, and finally the full incorporation of the change. Once the reorganization is fully adopted, the organization continues along until another need for a change becomes apparent to top management. This philosophy has met with success but fails to actually prevent the symptoms of malorganization from arising. Perpetual reorganization, on the other hand, is designed to prevent the symptoms from ever appearing.[1]

A second philosophy located somewhere between the extremes is that of *group decision*. This approach to reorganization rests on the belief that the human being's resistance to change is so strong that only by giving him his way can any change be successful. This democratic philosophy obtains the acceptance of the reorganization plan by the employees through their active participation. The decision they reach among themselves becomes the reorganization plan. This philosophy tends to relieve management of its responsibility for organization analysis which Dimock emphasized. This approach becomes an easy way out for a management which cannot effectively control and direct its organization. Efficiency is sacrificed which could otherwise be attained if management had managed its personnel instead of appeasing them.

CONCLUSION ON THE APPROACH TO REORGANIZATION

From the tone of this discussion it is apparent that *the soundest philosophy of reorganization is the perpetual or gradual approach*. In a well managed business by the process of giving intelligent consideration to the problems of organization at all times, all spasmodic and revolutionary changes are avoided. These are the changes and the nature of reorganization in which the real obstacles to successful reorganization are found.

In closing it should be emphasized that any reorganization plan is a good deal more than just the formal specifications proposed. As Barnard points out, "the greater part of a complete plan is unexpressed thought (intention), implied or assumed action not stated," and a lot more purposely not made explicit (1, p. 166). Reorganization thus assumes a change in both the formal and informal organizations. To carefully plan the reorganization down to the last detail is to foresee all conditions and situations that will arise under it. Only for the most immediate short run action is such refined planning practical. But because the basic theme of this paper has been to avoid the need for reorganizing for expediency purposes by perpetually reorganizing, it should be evident that reorganization is not a short run action. Hence the plan is not specified in complete detail; instead, it reshapes the formal organization on a broad enough basis to include an understanding of how the informal organization will be affected. In summary then, reorganization formally reorganizes the formal organization and informally reorganizes the informal organization.

[1] The perpetual approach can be distinguished from the accommodation approach in industry by the presence of a full time organization planning department such as that of the Standard Oil Company of California.

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A Mathematical Model for Production Scheduling in the Aircraft Industry[1]

by **ARJAN BHATIA**

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PRODUCTION Plans for any aircraft model usually exhibit three distinct phases, viz.: acceleration, constant rate and deceleration in production. In making a production schedule, factors such as sales commitment, manpower requirements and in-process inventory at different points in time are considered. This article develops a mathematical model for generating the starting and completion schedules for the assemblies and analyzes the effect of these schedules on manpower requirements and in-process inventory.

The general approach adopted in this article consists of:

1. Representing the completion schedule by some mathematical functions so that different schedules can be generated by suitably changing the values of the functional parameters.
2. Developing mathematical functions to represent the starting schedule from a consideration of assembly flow-time functions currently in use in the aircraft industry.
3. Developing expressions for the in-process assemblies, manpower requirements and hiring rate required for a given completion schedule.

CHARACTERISTICS OF THE COMPLETION SCHEDULE CURVE

The cumulative assembly and the completion rate curves are generally of the form shown in Figure 1. The first assembly is started at T_0 and completed at T_1. In the time interval between T_1 and T_2, the manufacturing program is accelerated; that is, the rate of completion of assemblies increases with time. In the time interval between T_2 and T_3, the assemblies are completed at a constant rate. In the time interval between T_3 and T_4, the manufacturing program is decelerated; that is, the rate of completion of assemblies decreases with time.

Let $X(t)$ denote the total number of assemblies completed up to time t. The function $X(t)$ can be partitioned into three distinct functions $X_1(t)$, $X_2(t)$ and $X_3(t)$.

$$\begin{aligned} X(t) &= X_1(t) \quad \text{for} \quad T_1 \le t \le T_2 \\ &= X_2(t) \quad \text{for} \quad T_2 < t \le T_3 \\ &= X_3(t) \quad \text{for} \quad T_3 < t \le T_4 \end{aligned} \qquad \text{Eq. 1.}$$

PRODUCTION INTERVAL FUNCTION

The acceleration part of the completion schedule (for $T_1 \le t \le T_2$) can be described by a function relating successive "production intervals." The yth production interval, $p(y)$, is defined to be the number of days between the completion of the yth and $(y+1)$th assembly. A family of functions of the following form will be considered.

$$p(y) = \frac{P(1-N)}{y^N} \quad 0 < N < 1,\ P > 0, \qquad \text{Eq. 2.}$$

and $y \ge 1$

where P and N are constants.

DERIVATION OF EXPRESSIONS FOR THE COMPLETION SCHEDULE

During the acceleration period $(T_1 \le t \le T_2)$, the time $t(X)$ at which Xth assembly is completed with a production interval function in Eq. 2. is given by

$$t(X) = T_1 + \sum_{y=1}^{X-1} p(y) \qquad \text{Eq. 3.}$$

Substituting for $p(y)$ from Eq. 2., Eq. 3. gives

$$X_1(t) \approx 1 + \left(\frac{t - T_1}{P}\right)^{1/(1-N)} \qquad \text{Eq. 4.}$$

By changing the values of P and N, a family of curves

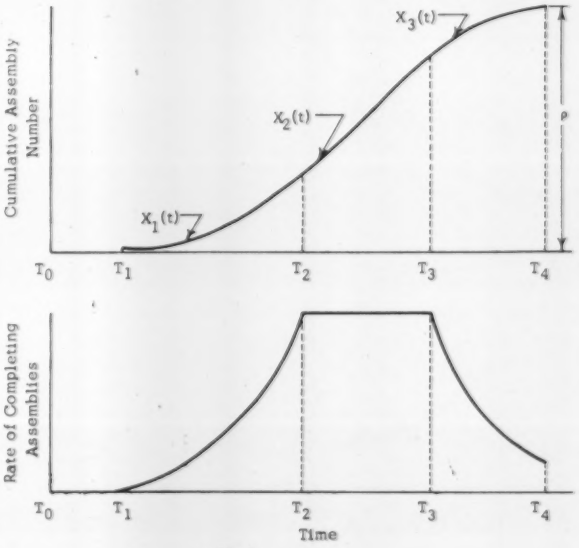

FIG. 1. Completion Rate.

[1] Based upon a presentation to the Seventeenth National Meeting of the Operations Research Society of America, May 18–21, 1960, in New York City.

for $X_1(t)$ can be generated, thus giving different completion schedules during the acceleration in production.

$X_2(t)$ represents the cumulative unit number during a time interval when the production rate is constant, and is therefore linear. It is therefore of the form

$$X_2(t) = bt + c \qquad \text{Eq. 5.}$$

where b and c are constants. Using boundary conditions:

$$\left(\frac{dX_2}{dt}\right)_{t=T_2} = \left(\frac{dX_1}{dt}\right)_{t=T_2}$$

and

$$X_2(T_2) = X_1(T_2),$$

Eq. 5. gives

$$X_2(t) = b(t - T_2) + \lambda \qquad \text{Eq. 6.}$$

where

$$b = \frac{1}{P(1-N)}\left(\frac{T_2 - T_1}{P}\right)^{N/(1-N)}$$

and

$$\lambda = 1 + \left(\frac{T_2 - T_1}{P}\right)^{1/(1-N)}.$$

Since $X_3(t)$ represents the completion schedule for the deceleration period, the rate of completing assemblies must be positive (since $X_3(t)$ denotes the cumulative assemblies completed at t) and must decrease with t during the deceleration period; that is, dX_3/dt must be positive and d^2X_3/dt^2 must be negative for $T_3 < t \leq T_4$. A function satisfying these conditions is given by

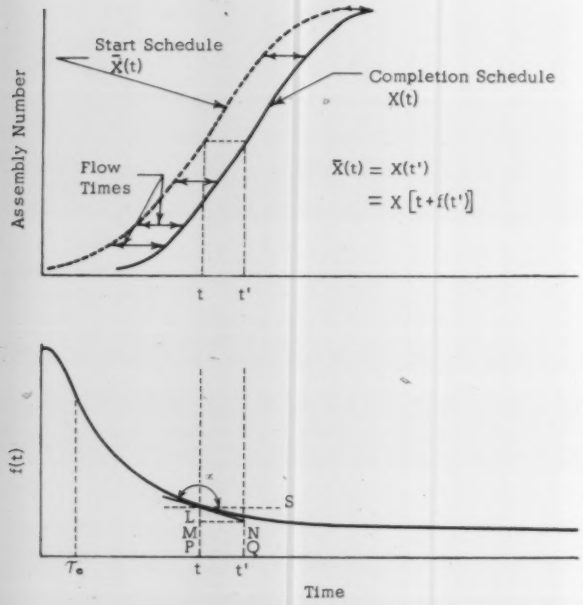

FIG. 2. Relation between Start and Completion Schedules.

$$X_3(t) = q - \frac{r}{t+s} \qquad \text{Eq. 7.}$$

where q, r and s are constants. Using the boundary conditions

$$X_2(T_3) = X_3(T_3),$$

$$\left(\frac{dX_2}{dt}\right)_{t=T_3} = \left(\frac{dX_3}{dt}\right)_{t=T_3}$$

and

$$X_3(T_4) = \rho,$$

where ρ = total number of airplanes to be manufactured; and solving for q, r and s, it can be shown that

$$X_3(t) = q - \frac{r}{t+s} \qquad \text{Eq. 8.}$$

where

$$q = \frac{\rho(T_4 + s) - \sigma(T_3 + s)}{(T_4 - T_3)}$$

$$r = \frac{(\rho - \sigma)(T_4 + s)(T_3 + s)}{(T_4 - T_3)}$$

$$s = \frac{T_4(\rho - \sigma) - T_3 b(T_4 - T_3)}{b(T_4 - T_3) - (\rho - \sigma)}$$

and

$$\sigma = X_2(T_3) = b(T_3 - T_2) + \lambda$$

FLOW TIME FUNCTION

The function expressing the flow time in assembly for a unit X, $f(X)$ commonly used in the aircraft industry is given by

$$f(X) = \frac{c_1}{(X - a_1)^{K_1}} \quad c_1 > 0; 0 < K_1 < 1; \quad \text{and } a_1 < 1 \qquad \text{Eq. 9.}$$

where c_1, K_1 and a_1 are known constants.

Let $f(t)$ = the flow time for the unit completed at time t. The function $f(t)$ can be obtained by substituting in Eq. 9. the expressions for X (Eq. 4., Eq. 6. and Eq. 8.).

RELATIONSHIP BETWEEN COMPLETION AND STARTING SCHEDULES

The starting time for the assembly completed at t can be obtained by subtracting from t the flow time for the assembly completed at t (Figure 2).

From Figure 2, it is seen that

$$\bar{X}(t) = X[t + f(t')] \qquad \text{Eq. 10.}$$

The slope of the function $f(t)$, df/dt is always negative and at first decreases rapidly up to τ_0 and then increases at a slower rate.

τ_0 is the inflection point of $\frac{df}{dt}$;

that is, $\frac{d^2f}{dt^2} = 0 \quad \text{at} \quad t = \tau_0.$

For $t \geq \tau_0$, assuming the $f(t)$ curve to be a straight line between t and t', it can be shown that

$$f(t') \approx \frac{f(t)}{1 - \left(\frac{df}{dt}\right)_t} \qquad \text{Eq. 11.}$$

---

where

$$\pi_1 = t + \frac{c_1\left[(1 - a_1) + \left(\frac{t - T_1}{P}\right)^{1/(1-N)}\right]}{\frac{c_1K_1}{P(1-N)}\left(\frac{t - T_1}{P}\right)^{N/(1-N)} + \left[(1 - a_1) + \left(\frac{t - T_1}{P}\right)^{1/(1-N)}\right]^{K_1+1}}$$

$$\pi_2 = t + \frac{c_1[bt + (\lambda - bT_2 - a_1)]}{bc_1K_1 + [bt + (\lambda - bT_2 - a_1)]^{K_1+1}}$$

and

$$\pi_3 = t + \frac{c_1\left[(q - a_1) - \frac{r}{t+s}\right]}{\frac{rc_1K_1}{(t+s)^2} + \left[(q - a_1) - \frac{r}{t+s}\right]^{K_1+1}} \qquad \text{Eq. 19.}$$

Substituting for $f(t')$, Eq. 10. gives

$$\overline{X}(t) = X\left[t + \frac{f(t)}{1 - \left(\frac{df}{dt}\right)_t}\right] \qquad \text{for } t \geq \tau_0 \quad \text{Eq. 12.}$$

The expression for τ_0 is obtained by letting

$$\left(\frac{d^2f}{dt^2}\right)_{t=\tau_0} = 0,$$

and is given by

$$\tau_0 = T_1 + P\left(\frac{N(1 - a_1)}{1 + K_1 - N}\right)^{1-N} \qquad \text{Eq. 13.}$$

STARTING SCHEDULE FUNCTIONS

The starting schedule function $\overline{X}(t)$ is composed of four distinct functions (Figure 3).

$$\begin{aligned} \overline{X}(t) &= \overline{X}_0(t) \quad \text{for} \quad T_0 \leq t \leq \tau_0 \\ &= \overline{X}_1(t) \quad \text{for} \quad \tau_0 < t \leq \tau_1 \\ &= \overline{X}_2(t) \quad \text{for} \quad \tau_1 < t \leq \tau_2 \\ &= \overline{X}_3(t) \quad \text{for} \quad \tau_2 < t \leq \tau_3 \end{aligned} \qquad \text{Eq. 14.}$$

where τ_0 is as defined in Eq. 13. and

$$\begin{aligned} \tau_1 &= T_2 - f(T_2) \\ \tau_2 &= T_3 - f(T_3) \end{aligned} \qquad \text{Eq. 15.}$$

and

$$\tau_3 = T_4 - f(T_4)$$

Eq. 4., Eq. 6., Eq. 8. and Eq. 12. give

$$\overline{X}_1(t) = 1 + \left(\frac{\pi_1 - T_1}{P}\right)^{1/(1-N)} \qquad \text{Eq. 16.}$$

$$\overline{X}_2(t) = b\pi_2 + (\lambda - bT_2) \qquad \text{Eq. 17.}$$

and

$$\overline{X}_3(t) = q - \frac{r}{\pi_3 + s} \qquad \text{Eq. 18.}$$

$\overline{X}_0(t)$ can be approximated by a function of the form

$$\overline{X}_0(t) = l(t - T_0)e^{m(t-T_0)} + n \qquad \text{Eq. 20.}$$

where l, m and n are constants to be determined from the following boundary conditions:

$$\begin{aligned} \overline{X}_0(T_0) &= 1 \\ \overline{X}_0(\tau_0) &= \overline{X}_1(\tau_0) \end{aligned} \qquad \text{Eq. 21.}$$

and

$$\left(\frac{d\overline{X}_0}{dt}\right)_{\tau_0} = \left(\frac{dX_1}{dt}\right)_{\tau_0}$$

θ and ϕ are defined such that

$$\begin{aligned} \theta &= \overline{X}_1(\tau_0) \\ &= 1 + \left[\frac{(\pi_1)_{\tau_0} - T_1}{P}\right]^{1/(1-N)} \end{aligned} \qquad \text{Eq. 22.}$$

and

$$\begin{aligned} \phi &= \left(\frac{d\overline{X}_1}{dt}\right)_{\tau_0} \\ &= \frac{1}{P(1-N)}\left[\frac{(\pi_1)_{\tau_0} - T_1}{P}\right]^{N/(1-N)} \cdot \left(\frac{d\pi_1}{dt}\right)_{\tau_0} \end{aligned} \qquad \text{Eq. 23.}$$

Using conditions Eq. 21. to solve for l, m, n, it can be

seen that

$$\overline{X}_0(t) = l(t - T_0)e^{m(t-T_0)} + n \qquad \text{Eq. 24.}$$

where

$$l = \frac{\theta - 1}{\tau_0 - T_0} e^{\left[\frac{\theta - \phi(\tau_0 - T_0) - 1}{\theta - 1}\right]}$$

$$m = \frac{\phi(\tau_0 - T_0) - (\theta - 1)}{(\tau_0 - T_0)(\theta - 1)}$$

and

$$n = 1$$

EQUIVALENT COMPLETION CURVE

At time t, $T_0 < t < T_4$, the number of assemblies started is always more than that of assemblies completed; that is, $\overline{X}(t) > X(t)$. $[\overline{X}(t) - X(t)]$ represents the assemblies in-process. Each of these in-process assemblies is at a different stage of completion, and we assume that the cumulative man-hours needed at time t is the sum of

1. Man-hours needed to complete $X(t)$ assemblies.
2. Man-hours needed to complete half of the in-process assemblies, i.e. $\frac{1}{2}[\overline{X}(t) - X(t)]$. This is based on the assumption that the man-hours expended for the completion of an assembly are uniformly distributed over its flow time.

We will name the curve representing the sum of the completed assemblies and half of the in-process units at various points in time as the "equivalent completion curve." The equivalent assemblies completed, $U(t)$ are given by

$$\begin{aligned} U(t) &= X(t) + \tfrac{1}{2}[\overline{X}(t) - X(t)] \\ &= \tfrac{1}{2}[X(t) + \overline{X}(t)] \end{aligned} \qquad \text{Eq. 25.}$$

Let

$$\begin{aligned} U(t) &= U_0(t) \quad \text{for} \quad T_0 \le t \le T_1 \\ &= U_1(t) \quad \text{for} \quad T_1 < t \le \tau_0 \\ &= U_2(t) \quad \text{for} \quad \tau_0 < t \le \tau_1 \\ &= U_3(t) \quad \text{for} \quad \tau_1 < t < T_2 \\ &= U_4(t) \quad \text{for} \quad T_2 < t \le \tau_2 \\ &= U_5(t) \quad \text{for} \quad \tau_2 < t \le T_3 \\ &= U_6(t) \quad \text{for} \quad T_3 < t \le \tau_3 \\ &= U_7(t) \quad \text{for} \quad \tau_3 < t \le T_4 \end{aligned}$$

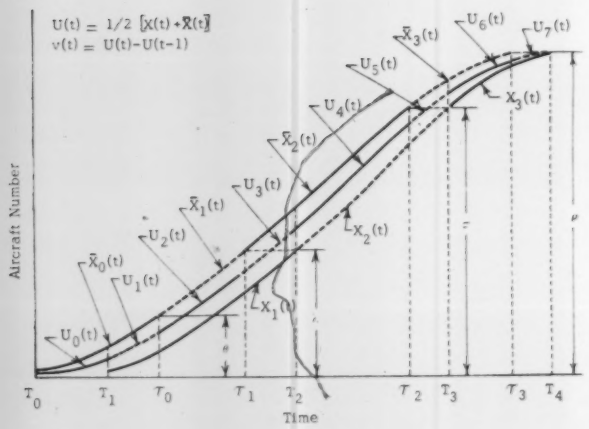

FIG. 3. Representation of a Schedule.

Using Eq. 25. and noting that approximately $t - T_0 / T_1 - T_0$ cumulative units are completed at time t for $T_0 \le t \le T_1$ (assuming that the fraction of the first unit completed is equal to the fraction of its flow time completed), the following equations are obtained

$$U_0(t) = \frac{1}{2}\left[l(t - T_0)e^{m(t-T_0)} + \frac{t - T_0}{T_1 - T_0} + 1\right] \qquad \text{Eq. 26.}$$

$$U_1(t) = \frac{1}{2}\left[l(t - T_0)e^{m(t-T_0)} + \left(\frac{t - T_1}{P}\right)^{1/(1-N)}\right] + 1 \qquad \text{Eq. 27.}$$

$$U_2(t) = 1 + \frac{1}{2}\left[\left(\frac{\pi_1 - T_1}{P}\right)^{1/(1-N)} + \left(\frac{t - T_1}{P}\right)^{1/(1-N)}\right] \qquad \text{Eq. 28.}$$

$$U_3(t) = \frac{1}{2}\left[b\pi_2 + \left(\frac{t - T_1}{P}\right)^{1/(1-N)} + (\lambda - bT_2 + 1)\right] \qquad \text{Eq. 29.}$$

$$U_4(t) = \frac{b}{2}(\pi_2 + t) + (\lambda - bT_2) \qquad \text{Eq. 30.}$$

$$U_5(t) = \frac{1}{2}\left[b\pi_2 - \frac{r}{t + s} + (\lambda - bT_2 + q)\right] \qquad \text{Eq. 31.}$$

$$U_6(t) = q - \frac{r}{2}\left(\frac{1}{\pi_3 + s} + \frac{1}{t + s}\right) \qquad \text{Eq. 32.}$$

$$U_7(t) = \frac{1}{2}\left[(\rho + q) - \frac{r}{t + s}\right] \qquad \text{Eq. 33.}$$

The "equivalent completion curve" is illustrated in Figure 3.

MANPOWER REQUIREMENTS

The function expressing the man-hours needed to assemble the unit X, $h(X)$ commonly used in the aircraft industry is given by

$$h(X) = \frac{c_2}{(X - a_2)^{K_2}}$$

$$c_2 > 0,\ 0 < K_2 < 1,\ \text{and}\ a_2 < 1 \qquad \text{Eq. 34.}$$

where c_2, K_2 and a_2 are known constants.

Man-hours needed during any time interval can be calculated by multiplying the equivalent assemblies completed in the time interval, by the average man-hours per

assembly during the interval. Thus man-hours needed between the time interval $(t-1, t)$ will be denoted by $h(t)$ and are given by

$$h(t) = \frac{c_2 v(t)}{[Z(t) - a_2]^{K_2}} \qquad \text{Eq. 35.}$$

where

$v(t)$ = equivalent assemblies completed in the time interval $(t-1, t)$
$= U(t) - U(t-1)$

and

$Z(t)$ = assembly number, the man-hours needed for the completion of which represent the average man-hours per assembly during the time interval $(t-1, t)$.
$\approx \frac{1}{2}[U(t) + \overline{U}(t)]$

Manpower requirements in the interval $(t-1, t)$ will be denoted by $m(t)$, and are given by

$$m(t) = \frac{h(t)}{157.2} = \frac{c_2 v}{157.2(Z - a_2)^{K_2}} \qquad \text{Eq. 36.}$$

where 157.2 represents average man-hours per man-month; units of time being assumed to be months.

Manpower to be hired in the time interval $(t-1, t)$ will be denoted by $\psi(t)$ and is given by

$$\psi(t) \approx m(t) - m(t-1) + \gamma m(t-1) \qquad \text{Eq. 37.}$$

where γ = attrition rate expressed as a percentage of the employed manpower leaving per unit time.

Another important factor that is considered in production scheduling is the "manpower accession rate." It is defined as the ratio of the hiring rate to the manpower level. Expressed as a percentage, the manpower accession rate $\Gamma(t)$ is given by

$$\Gamma(t) = \frac{\psi(t)}{m(t)} \times 100 \qquad \text{Eq. 38.}$$

IN-PROCESS UNITS

The assemblies in process I at various points in time are given by

$$I(t) = \overline{X}(t) - X(t) \qquad \text{Eq. 39.}$$

where $\overline{X}(t)$ and $X(t)$ are substituted from Eq. 4., Eq. 6., Eq. 7., Eq. 16., Eq. 17., Eq. 18. and Eq. 20.

USE OF THE MATHEMATICAL MODEL

The equations developed so far for the generation of a schedule have been written in terms of the time parameters T_0, T_1, T_2, T_3 and T_4; the learning function constants c_1, c_2, K_1, K_2, a_1 and a_2; the production interval function parameters P and N; and the total aircraft to be manufactured, ρ. In practice, the learning function constants c_1, c_2, K_1, K_2, a_1 and a_2 are known. Some of the remaining parameters T_0, T_1, T_2, T_3, T_4, P, N and ρ may further be known, and by giving different values to the others, different schedules with different manpower and in-process inventory characteristics can be generated. The equations can be programmed on an electronic computer and the schedules can be generated with high speed.

The mathematical model can be very profitably used during preliminary planning or bidding for a new contract. The preliminary planning is usually done for the acceleration and constant rate phases of the contract, and the planning for the deceleration phase of production is postponed, hoping to receive more orders at a later date. Under these conditions, P, N and T_0 can be calculated if we assume that

1. $T_3 = T_4$; i.e. there is no deceleration.
2. T_1, T_2, T_3 and ρ are provided as input.
3. The maximum production rate b is decided by the management and provided as input.

From Eq. 4. and Eq. 6. it can be shown that

$$N = 1 - \frac{\lambda - 1}{b(T_2 - T_1)} \qquad \text{Eq. 40.}$$

and

$$P = \frac{T_2 - T_1}{(\lambda - 1)^{(\lambda-1)/b(T_2-T_1)}} \qquad \text{Eq. 41.}$$

where

$$\lambda = \rho - b(T_3 - T_2)$$

T_0 is given by

$$T_0 = T_1 - f(T_1) = T_1 - \frac{c_1}{(1 - a_1)^{K_1}} \qquad \text{Eq. 42.}$$

EXAMPLE

The ideas developed so far will now be illustrated by means of a hypothetical example.

It is proposed to complete 71 aircraft assemblies in 30 months by accelerating production in such a way that a peak completion rate of 6 assemblies per month is reached at the end of the 24th month. The first unit is completed at the end of the fifth month. The coefficients for the learning functions and the attrition rate constant are assumed as follows:

$c_1 = 5$
$c_2 = 233{,}600$
$K_1 = .32193$
$K_2 = .32193$
$a_1 = 0$
$a_2 = 0$

and

$\gamma = 0$

COMPUTER OUTPUT

$P=6.6374$ $N=0.70175$ $P=71.00$ $T_0=0$ $T_1=5$ $T_2=24$ $T_3=30$ $T_4=30$

T	$\bar{X}$	X	U	k	m	ψ	Γ	f
...	....	...	....	.....	....	...	....	....
15.	9.23	5.0	7.09	185072.	1177.	153.	13.0	2.99
16.	11.27	6.4	8.86	211216.	1344.	166.	12.4	2.75
17.	13.67	8.3	10.98	236789.	1506.	163.	10.8	2.53
18.	16.49	10.5	13.51	263972.	1679.	173.	10.3	2.34
19.	19.77	13.2	16.49	291457.	1854.	175.	9.4	2.18
20.	23.55	16.4	19.97	319204.	2031.	177.	8.7	2.03
21.	27.88	20.1	23.99	347608.	2211.	181.	8.2	1.90
22.	32.81	24.4	28.61	376564.	2395.	184.	7.7	1.79
23.	38.28	29.4	33.82	401862.	2256.	161.	6.3	1.68
...	.....	....	.....	.....	....	...	...	....

FIG. 4

From the data provided, it is clear that

$$\rho=71$$
$$T_1=5$$
$$T_2=24$$
$$T_3=T_4=30$$

and

$$b=6$$

Using Eq. 40., Eq. 41. and Eq. 42., we get

$$N=0.70175$$
$$P=6.6374$$
$$T_0=0$$

The equations developed in this article can then generate the starting and completion schedules along with the manpower requirements. These equations were programmed on the IBM 704 computer and a sample output for this example is shown in Figure 4.

BASIC APPROACH TO OPTIMIZATION

The schedule has been represented mathematically by $X(t)$ and $\overline{X}(t)$. The variable parameters of the functions are P, N, T_0, T_1, T_2, T_3 and T_4.

Any feasible schedule must not violate any of the known restrictions such as manpower availability, position and tooling facilities, etc. Requirements due to a completion schedule can be presented as function of P, N, T_0, T_1, T_2, T_3 and T_4.

If there are g restrictions $R_1, R_2, \cdots, R_g$, and the functions representing the requirements due to a schedule are $f_i(P, N, T_0, T_1, T_2, T_3, T_4)$, $i=1, 2, \cdots, g$ following inequalities can be written

$$\begin{aligned} f_1(P, N, T_0, T_1, T_2, T_3, T_4) &\leq R_1 \\ f_2(P, N, T_0, T_1, T_2, T_3, T_4) &\leq R_2 \\ &\vdots \\ f_g(P, N, T_0, T_1, T_2, T_3, T_4) &\leq R_g \end{aligned} \qquad \text{Eq. 43.}$$

One important objective to be achieved may be a minimum cost for the program. Cost of a program C may be written as a function of P, N, T_0, T_1, T_2, T_3 and T_4.

Thus

$$C = f_0(P, N, T_0, T_1, T_2, T_3, T_4) \qquad \text{Eq. 44.}$$

The optimum scheduling problem can then be restated as that of determining P, N, T_0, T_1, T_2, T_3 and T_4 such that inequalities Eq. 43. are not violated and the function in Eq. 44. is minimized. If the restraints and the objective function as shown in Eq. 43 and Eq. 44. can be formed for a practical problem, it would be possible to use nonlinear programming techniques to get an optimal schedule.

CONCLUSIONS

The mathematical model can be used to generate a large number of schedules with different manpower and in-process inventory characteristics, and can be profitably used especially during preliminary planning. It can be used as a basis for optimizing schedules.

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The Human Relations of Management Techniques

by **JOSEPH GLASSER**

Department of Industrial Administration, The University of Connecticut

WHENEVER industrial management is discussed, major emphasis is given to the various techniques that it embodies. Among others these include plant layout, methods analysis, time study, job evaluation, and merit rating. Conferences and symposiums are replete with reports of examples of companies where properly installed modern management techniques have brought tremendous improvements in operations, both in production and in personnel relations. However, most of these reports fail to indicate that the use of these very same management techniques has brought a number of other companies production and personnel problems.

TECHNIQUE ADAPTABILITY

One company will find that a specific management technique has effected cost reductions or increased productivity and as a result improved its profit position. Another feels that it will also obtain these results by the duplication of the same procedure. However, the second company may find that it has gained none of the benefits which have accrued to the first. Instead, it may find its production disrupted and its workers dissatisfied, with a resultant lower profit position. Thus the evidence regarding management techniques seems inconclusive; a specific technique can be either a panacea or a problem.

It goes without saying that none of these management techniques can, of itself, affect the outcome of its utilization. They are inanimate, and are incapable of exercising any influence upon a company's operation, favorable or unfavorable. It is only in the way that a management administers these techniques that these different effects occur.

It is essential, then, to examine the management of various companies to gain an understanding of the successes and the failures of industrial management techniques. The characteristics which bring profitable operations in one case are usually lacking in the company where the same technique brings about a negative effect.

Each company must adapt any management technique that it uses to its own needs. Some companies have attempted to use the exact details of a program which has had success in another company, and do not experience the same results. This occurs because the duplication of another company's program does not fit the needs of the company presently using it. It is the responsibility of management to develop the details of a program designed for its needs. Failure to take this fact into account may be a primary reason for the unsatisfactory results of a new program.

TOP MANAGEMENT SUPPORT

No matter what program a company wishes to integrate into its operations, it is imperative that it receive the full support of top management. Merit rating will be used as an example, but this rule applies equally to other management techniques. Merit rating may be introduced into a company after an executive has attended a conference or read an article about the benefits of a merit rating program. He will call in his subordinates and inform them what he has learned. They may be instructed to put a merit rating program into effect immediately. These lesser executives communicate this information to their subordinates and so on down the levels of the line organization. The communication process stops at the foremen, who are to carry out the merit rating, as they are in direct contact with the workers and can thus give the best evaluation of their performances.

Each level of management may feel that it has carried out its responsibility when it has transmitted the order to its subordinates. This is the crux of the problem. The foremen attach little importance to merit rating; as it is just another order coming down through channels. They feel that this is another chore which their superiors have avoided by passing it down to them. Thus, in this type of situation, merit rating becomes nothing more than additional paperwork for the foremen, diverting more of their attention from the problems of production. Any advantages which might have been gained are lost because top management has failed to give its support to the program. Its importance is lost when it becomes just another order passed down by top management, without further explanation of its purpose and its advantages to the foremen and the workers.

EMPLOYEE ACCEPTABILITY

In a good many cases, the success or failure of any management technique is dependent upon the entire program of a company. If a company has had a continuous record of poor relationships with its employees, the success of any management technique is not as likely as would be the case where a company had had a good relationship with its workforce. Worker distrust of management in the former case becomes second nature, and any company innovation would be regarded as an attempt to take further advantage of the workers. This

situation is not easily corrected; this can only be accomplished over a period of time by the sincerity of management's acts. A new pattern of management-worker relationship evolves very slowly, and management's impatience can forestall its development.

Although it is the decision of management whether any of these techniques will be used, the success of the technique cannot be as easily determined by management. A program can be successful only if those who must work under that program accept it. Workers tend to be wary of management techniques because of the uncertainty that an innovation brings. If the employees do not know the purposes or the effects which management may have in mind, the resulting insecurity precludes the likelihood of acceptability.

The use of time study can serve as an example. If it is introduced into a plant without any prior notification to the workers, it is quite likely to precipitate production and personnel disturbances. Resentment arises because of worker misapprehension, not from disagreement with time study *per se*. On the other hand, a company contemplating the use of time study should make the workers and their representatives aware of its proposed action. The management should also indicate what it hopes to accomplish by installing time study and what the effect will be upon the present workforce. By this procedure, uncertainty and the concomitant insecurity is minimized. The negligible worker resentment that might occur would not cause production and personnel disruptions. Even if acceptability is not immediately forthcoming, the company will not be burdened with outright rejection and its consequences.

WORKER EDUCATION

Most of the techniques available to management are designed to improve production and personnel relations, so that a better profit position can be secured. This fact is unknown to the workers, so that when a new procedure is introduced, the workers feel that the conditions which presently exist are being changed for the improvement of the company's financial status. Workers feel that they gain nothing, as these changes are the unilateral actions of management for the advantages which accrue only to management.

Workers resistance to management techniques has become the pattern because of the abuse which management has traditionally given the worker group. Selfish interests of the company have predominated over any other considerations; the effects of these practices upon the workforce are given little thought. Because of this approach by management, workers regard all innovations with suspicion, even though they are capable of improving the workers' position. Methods analysis or work simplification furnishes a good illustration of this point. In many instances, workers will claim that a new method is more difficult and time-consuming than the former method. These workers actually believe this to be the case because they have been conditioned to this from past practices, even though it could be shown that the same output could be accomplished with less movement and less effort.

It is necessary for management to undertake a continuous program of educating their employees to the fact that many management devices, not only bring better results to management but also bring better conditions to the workers.

The technique of plant layout has been used to great advantage in many companies. A thorough rational analysis of the production procedures in most plants can reduce much of the backtracking, confusion, and delays which are present. Occasionally, after an expensive and extensive rearrangement of the plant facilities in accordance with a plant layout analysis, the hoped-for results are not achieved. All computations show that certain results should be present, but the revised production layout gives little or no improvement.

WORKER SOCIAL PATTERN

Many managements fail to realize that the factory provides more than just an industrial environment for its workers. A pattern of social interaction develops among the workers as they come into contact with each other while on the job. This may have both positive and negative effects. Where friendly relationships exist, workers will cooperate with each other with resulting increases in production. Where these associations are antagonistic, the ensuing conflict will reduce production. Where unfriendly relations develop, transfers may be used to minimize this problem.

A revised plant layout can disrupt the social pattern of the workforce, with its resultant worker dissatisfaction. Management, in planning the revision of its plant facilities, should minimize the alteration of the social pattern by instituting gradual changes. This will allow a new pattern of relationships to arise and there will be no violent transformation of the social environment. The maximum benefits of plant layout can thus be secured.

The unilateral action of management in the development and introduction of these various techniques has already been mentioned. The workers in a plant may know nothing about management's intentions until the inception of these practices. This results in the distrust and resistance previously explained. In addition to this, management fails to gain much information which can effect the successful operation of the technique.

WORKER PARTICIPATION

Workers are closer to the jobs than anyone else in the company. Their intimate knowledge of and experience with their jobs can furnish much information which can

be of value in the application of these various techniques. If the suggestions of the workers are actively solicited by management, there will be a greater likelihood of success. When workers feel that they have participated in the development of a management program, they will give their full cooperation in seeing that the technique accomplishes its objectives as much as possible.

The philosophy of management has an important bearing on the outcome of its various practices. This is the crux of the question as to whether management techniques are the panacea or the problem. Empathy is the solution to this perplexing situation; this is the human relations approach. All of the concepts discussed are based upon an understanding of the feelings and the motivations of management's subordinates, especially of the workforce.

SUMMARY

In brief, the points discussed in this analysis of management are:

1. Any industrial management technique must be adapted to the needs of the company.
2. It is necessary to have top management support for any contemplated program.
3. Management may gain worker acceptability for its program by reducing the uncertainty that change can engender.
4. By educating workers to the benefits which they receive from a management technique, a company is likely to have greater success in achieving its purpose.
5. Management should recognize the social pattern of the industrial environment. The innovation of a management technique should be accomplished with the smallest possible disruption to this pattern of worker relationships.
6. Worker participation in the development of management techniques will have a great influence on their ultimate success.

A Classification of Inventory Control Theory

by **THOMAS L. NEWBERRY**

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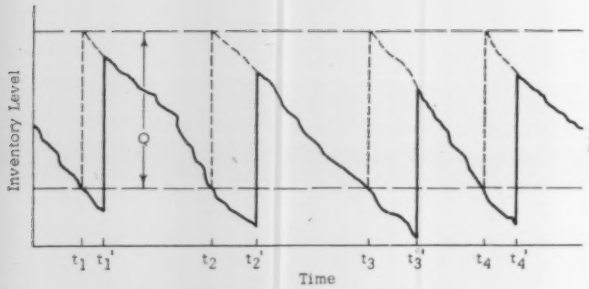
MANY excellent works in the theory of inventory control have appeared in the literature in the past decade. Authors, with great sophistication, have delved deeply into special inventory conditions. The results of these labors are most praiseworthy; however, there lacks a unification, or classification, of inventory control theory into a logical body of knowledge. It is the purpose of this article to suggest one possible classification plan and a partial bibliography of references for this system.

INVENTORY POLICIES

The most commonly used inventory control policies will be discussed prior to the consideration of the developments which have occurred in inventory control theory. The general characteristics of these policies are shown in Figures 1 through 5. The demand for the items in this inventory is, as in the general case, variable, and the lead time (time between placing an order and receiving the order) is also variable. The term "cycle" is used to denote the period of time between successive order placements.

The figures corresponding to the first four policies considered are applicable to goods received in discontinuous quantities from the vendor. However, these figures can be applicable to inventories in manufacturing establishments by considering the vertical line which represents the receipt of an order to have a slope corresponding to the production rate. Although it is natural to expect that the production rate will be reasonably constant, the elapsed time between the production order being initiated and the actual start of production will in most cases be subject to variation. A summary of the important features of these policies is as follows:

1. *Fixed Quantity Policy* (see Figure 1). The inventory is examined continuously. A fixed order quantity, Q, is placed when the stock level declines to a reorder point, regardless of the time between orders.
2. *Fixed Cycle Policy* (see Figure 2). The inventory is examined at the end of each constant time interval, Δt. An order is placed each time interval which is based upon the quantity consumed during the reorder cycle time interval (maximum quantity, S, minus the quantity on hand at the end of period i, x_i).
3. *Fixed Cycle-Quantity Policy* (see Figure 3). The inventory is examined continuously. A fixed order quantity, Q, is placed if the stock level declines to the reorder point before the end of each constant time interval, Δt. If the inventory level is greater than the reorder point during the time interval, Δt, an order is then placed at the end of each time interval which is based upon the quantity consumed during the reorder cycle time interval (maximum quantity, S, minus the quantity on hand at the end of period i, x_i).
4. *The (s,S) Policy* (see Figure 4). The inventory is examined at the end of each constant time interval. An order is placed if the quantity on hand is less than a specified level, s, which is based upon the quantity consumed since the most recent order



——— Quantity on Hand
– – – – Quantity on Hand and on Order
t_i is the time when the ith order is placed.
t_i' is the time when the ith order is received.
Q is the fixed order quantity.

FIG. 1. Inventory Balances for Fixed Quantity System.

was placed (maximum quantity, S, minus the quantity on hand at the end of period i, x_i). If the quantity on hand is greater than the specified level, s, no order is placed.

5. *Variable Input and Output System* (see Figure 5). Characteristic of this inventory situation is the closed system formed by an organization in which specific items that require maintenance from time to time serve as major components for an assembly. An item is, at any one time, being either a part of the assembled unit, or being reprocessed, or being in storage awaiting use. Among the decisions to be made is the total number of units of the item to have on hand. In this situation the time between successive demands is usually variable and the time required for maintenance is a variable depending upon the nature of the maintenance. Hence, the input to the inventory (spares) and also the output is variable, depending upon the nature of the demand and the maintenance facility.

This system has particular application to the Armed Forces in which assemblies often consist of several independent items; therefore, when an item needs maintenance, a spare item is used as a replacement with the removed item undergoing a maintenance procedure. (Examples: aircraft, radar, and missile components.) Specifically, this policy is also applicable to private corporations in the transportation industry where the removed items may be engines.

The foregoing policies have received a varying degree of attention by inventory control theorists, who have often found it necessary to accompany their theoretical treatments with strict assumptions regarding the nature of the elements associated with the inventory problem.

The solution to the inventory problem may be of two types. An optimum decision may be desired which will minimize the sum of the setup cost and the holding cost subject to tolerating a specified probability of a shortage. This first type of solution is only applicable when stochastic processes are involved. The second type decision may be desired which will minimize the sum of setup cost, holding cost, and shortage cost. This second type of solution is applicable if the variables are either all deterministic or all stochastic or a combination of both. Some of the elements which should be considered in obtaining the solution of the inventory problem are as follows:

1. The cost of the unit may be constant or variable.

2. The holding cost may be constant or variable. This cost is usually considered as a constant percentage of the cost of the product.

3. The cost of a shortage may be known or unknown, often assumed to be either zero cost or infinite cost. The cost of a shortage will often be composed of intangible components.

4. Back orders may be permitted or not permitted. It is often assumed that a customer will tolerate a delay in the acquiring of a purchased item. Loss of good will may be incurred by this delay to the customer.

5. The demand may be constant or variable. Demand is often assumed to be constant.

6. The recorder lead time may be constant or variable. The lead time is often assumed to be constant.

7. The goods in inventory may be of a discrete or continuous nature.

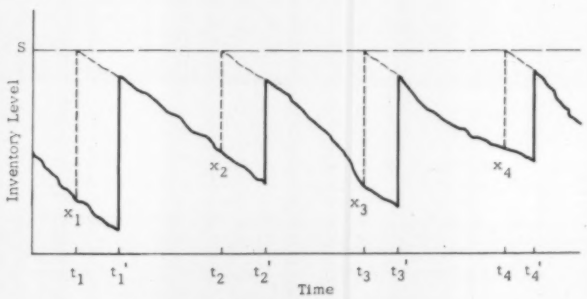
8. The quantities may be received into inventory in a discontinuous manner, example (receipt of goods from vendor) or in a continuous manner, example (receipts from production line).

9. The quantity of items received may be identical with the quantity of items ordered, or the items received may have some random fluctuation about the average items ordered. (Examples: agricultural production, job lot production when stringent quality requirements exist, or batch production in a refinery.)

HISTORY OF INVENTORY CONTROL

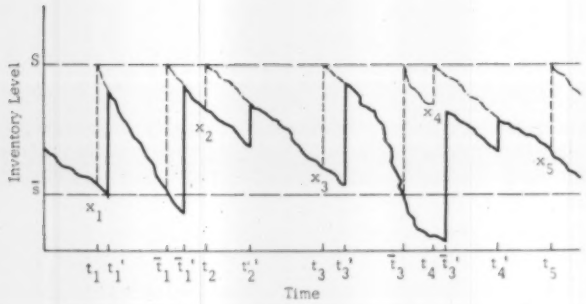
Since the fixed quantity inventory policy was the only inventory policy which had been given significant mathematical treatment prior to the 1950's, this section will be mostly concerned with this policy. Shortly after the principles of scientific management, as suggested by Frederick W. Taylor, were beginning to be adopted by the more progressive industrial concerns, it was determined that the unit cost of an item also depended upon the size of the production lot because of the fixed setup cost. This appreciation caused an increasing amount of interest in ascertaining the proper economic lot size.

In 1912 George Babcock attempted to determine a mathematical basis for lot sizes by use of a cubic equation, evidently an arbitrary equation (43, pp. 119-120). However, F. W. Harris used the economic lot size in 1915 at the Westinghouse Electric and Manufacturing Com-



——— Quantity on Hand
– – – – Quantity on Hand and on Order
t_i is the time when the ith order is placed.
t_i' is the time when the ith order is received.
S is the maximum stock level.
t_i-t_{i-1} is constant.

FIG. 2. Inventory Balances for Fixed Cycle System.



——— Quantity on Hand
– – – – Quantity on Hand and on Order
t_i is the time when the ith order is placed.
t_i' is the time when the ith order is received.
$\bar{t}_i$ is the time when the 2nd order in the ith period is placed because of declining below $\bar{s}$.
$\bar{t}_i'$ is the time when the 2nd order in the ith period is received.
$\bar{s}$ is the inventory level below which an order must be placed immediately.

FIG. 3. Inventory Balances for Fixed Quantity or Cycle System.

pany; this formula was almost identical to the present accepted economic lot size formula (43, pp. 121-122).

$$Q = \sqrt{\frac{PS}{C}}\, k,$$

where
Q is economic production quantity,
P is cost of preparing for the manufacture of a lot,
S is daily rate of sales,
C is unit production cost, and
k is a constant which includes not only the interest rate but also other factors such as storage cost, insurance, and taxes.

Harris emphasized the necessity for insuring that the assumptions under which the economic lot size formula is based are applicable.

Controversies quickly arose between accountants and engineers over 1. the inclusion of interest as an item of cost and 2. the attempt of the engineers to minimize certain factors which were previously included in overhead.

In 1918 the economic lot size was modified by E. W. Taft to account for the fact that the manufacturing period and sales period overlap since some of the production items are diverted to current orders without entering the inventory (43, p. 126). The economic lot size then becomes

$$Q = \sqrt{\frac{PSD}{Ci(D - S)}},$$

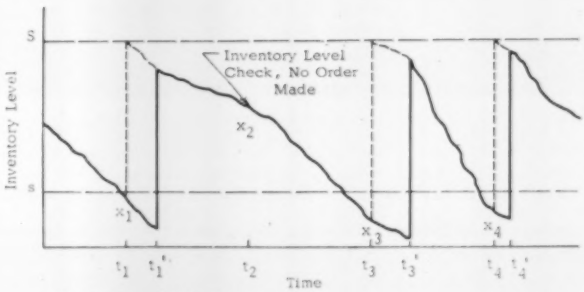
where D is the rate of production and i is interest rate. Taft later argued that the unit cost of capital should be employed along with the unit manufacturing cost in evaluating inventories (43, pp. 126-127). This method results in compounding the cost of capital in each step of the manufacturing process.

In 1923 F. H. Thompson of the Dennison Manufacturing Company developed an additonal factor into the formula which handles the cost of storage space on the basis of bulk rather than value (43, pp. 127-128).

Between 1923 and 1931 few new developments were recorded with regard to economic lot size formulae. In the classic treatise on *Quantity and Economy in Manufacture* by Fairfield E. Raymond, which appeared in 1931, an attempt was made to include all factors into one formula that might conceivably effect the economic lot size. This book is probably the most complete treatment on the subject of economic lot sizes, including the recent treatments by operations research oriented people. Very few of his recommended procedures for determining economic lot sizes were applied to production problems in the following years, possibly due to the economic conditions of the thirties. Many of these topics have appeared recently in technical journals, with little or no acknowledgement being attributed to Raymond. Among the many topics appearing in this monumental book are the following:

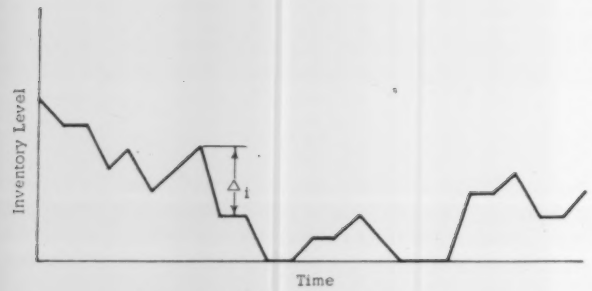
1. The limits of the economic range for lot sizes is determined in order to give production executives a range of possible lot sizes where "little" difference existed in unit cost.
2. An allowance for spoilage and salvage is considered.
3. The influence of seasonal demand upon production scheduling is considered.
4. An elaborate discussion is given to space charges.
5. Deterioration and obsolescence are quantitatively considered.

Chronologically, the next work of any importance can be attributed to Erich Schneider in 1938 (53). However, the language barrier was a principal deterrent to the use of any of the concepts mentioned. Schneider's problem is to minimize the combined costs of production and storage when 1. the sales forecast is given as a function of time, 2. the initial inventory is given, 3. certain ca-



——— Quantity on Hand
– – – – Quantity on Hand and on Order
t_i is the time when the ith order may be placed.
t_i' is the time when the ith order is received.
S is the maximum stock level.
s is the inventory level at which the stock on hand must be below before an order is placed.

FIG. 4. Inventory Balances for the S-s System.



Δ_i is the change in inventory level on day i (input — output).
FIG. 5. Inventory Balances for Variable Input and Output System.

pacity restrictions exist, and 4. carrying costs and production costs are known.

There were few, if any, major developments in the field of inventory control between 1938 and 1951.

RECENT DEVELOPMENTS IN INVENTORY CONTROL

The most important achievements in the area of inventory control since the inventory control analysis of Erich Schneider in 1938 were the papers submitted by Arrow, Harris, and Marschak in 1951 (3) and Dvoretzky, Kiefer, and Wolfowitz in 1952 and 1953 (16) (17) (18). These achievements have prompted considerable advances in the basic theory of inventory control. Prior to 1951 most of the developments in inventory control assumed the elements of the inventory problem to be of a fixed, or deterministic nature.

In the first part of this section references will be noted where the consideration of inventories will be on a per unit basis, in contrast to considering items on an aggregate basis in the second part. Inventories are considered by aggregate item analysis if 1. each item is not considered in all its detail or 2. the item is considered in detail and some measure of all the items must fulfill some overall constraint.

SINGLE ITEM ANALYSIS

Typical of single item analysis is the use of the economic lot size formula for the determining of production quantities or purchase quantities for a single item.

Fixed Quantity Policy.—Some additional factors may need to be added to the traditional economic lot size (fixed quantity) formula under certain conditions. Bhattacharjee suggests that the unit holding costs for work-in-process should be considered when there is considerable demand for the item (7). Grassi and Gradwohl determine a modified economic lot size formula which includes the effect of obsolescence providing that obsolescence can be stated in statistical terms (26). Llewellyn determines the lot size to produce in order to compensate for scrappage losses in manufacture (35). (The quantity produced is subject to random variation.) Smith illustrates the relationship between economic lot size theory and break-even analysis (45).

Some of the recent texts in inventory control have considered the buffer, or safety, stock required for varying levels of protection when there exist stochastic processes in the inventory system (36) (47) (57). Vazsonyi determines the safety stock when demand varies according to the normal distribution (47, pp. 330-338). Whitin determines the safety stock required for a specified level of protection when the demand is Poisson (57, pp. 42-46). Several authors have considered the case in which both the demand and also the lead time are stochastic processes (5) (12) (13) (28). Morris describes techniques for handling stochastic variables when the exact distribution and the nature of the parameters are unknown (38).

Salveson criticizes the use of the economic lot size formula when it is used to determine production quantities for two or more items which share the same production facility (44). In a simulation of a single stage production system, Conway concluded that interdependence existed between the different products produced in this single stage production system and that traditional economic lot size formulae would result in non-optimum lot sizes (14, p, 129).

Fixed Cycle Policy.— The fixed cycle policy has received little analytical attention with regard to determining the maximum level, S, and the length of the period, $\triangle t$. Vazsonyi has an excellent analytical discussion for determining the maximum level, S, when the length of the period, $\triangle t$, is given and demand is variable (47, pp. 338-345). Whitin determines the optimum length of the period, $\triangle t$, when the demand is variable; the maximum level, S, is obtained by adding the expected demand during the length of the period to the safety stock required for any desired level of protection (57, pp. 46-52). Gaver rigorously determines the optimum maximum level, S, where the demand is variable and unfilled demand is lost (22). Naddor (40) and Churchman (10) present some simple models with variable demand which determine optimal values of the maximum level, S. A method for the joint determination of both S and $\triangle t$ for optimal fixed cycle policies is not readily available in the literature.

Fixed Quantity or Cycle Policy.—Very little mention is made of this policy; Whitin states that the General Services Administration operates under this type of inventory policy (57). One of the domestic airlines is known to maintain several thousand parts under this policy. No analytical research is known to have been performed with regard to this inventory policy.

The (s, S) Policy.—Arrow, Harris, and Marschak consider in their classic paper fixed models, uncertain models, static models, and dynamic models; also in this article a procedure is derived for obtaining optimal values of s and S in the (s, S) policy given that the length of the period, Δt, is specified (3). Dvoretzky, Kiefer, and

Wolfowitz have written three highly theoretical inventory control papers. Their first article is concerned with determining the optimal ordering policy when the demand distribution is known (16); the second article is concerned with the optimal ordering policy when the demand distribution is unknown (17)[1]; and the third article describes necessary and sufficient conditions for the validity of the (s, S) policy (18). All four of the articles referenced in this paragraph are highly mathematical; these articles have not been translated into any form suitable for application purposes. A recent book by Arrow, Karlin, and Scarf is mostly concerned with additional mathematical concepts and implications of the (s, S) policy (4). The (s, S) policy has received more analytical treatment of a general nature than have any of the other policies.

Variable Input and Output Systems.—With the exception of some queueing studies based upon strict assumptions, very little work has been published regarding a method of determining the optimal number of items to have in a closed system of this type. Research in the School of Industrial Engineering at Georgia Institute of Technology is presently being conducted; only specific solutions to specific problems by Monte Carlo methods are being attempted.

By considering two or more possible degrees of maintenance activities for a given situation, the problem rapidly departs from that of the simple queueing model.

Other Inventory Systems.—Not all inventory systems can be described as one of the foregoing policies. Gass describes the use of linear programming in scheduling employment and production when the demand is seasonal (21, pp. 159-164). Holt, Modigliani, Muth, and Simon develop methods for scheduling employment and production when the cost function is not linear but quadratic (31) (32).

Eagle develops decision rules for determining a maximum level, S, when demand, the reorder period, and the lead time are variables (19).

Whitin, Youngs and Heyvaert are concerned with the development of an inventory policy when the demand is variable and extremely low (29) (55). Beckman determines an optimal policy for variable demand where extremely long delivery lags exist (6).

AGGREGATE ITEM ANALYSIS

The use of single item analysis may not be suitable for all situations. Inventory control procedures for a specific situation may be such that it is not practical to study in detail each item and compromises may need to be made—for example, classifying all items into categories depending upon the ratio of setup (or order) costs to the percentage of inventory carrying costs (25). The study of each item may be possible, but some aggregate measure of all items must fulfill a specified constraint—for example, the total inventory investment must be less than a specified value.

Gross Considerations.—Welch has developed a technique for considering inventory items that can be classified into broad categories (49). The RAND Corporation has been particularly interested in developing practical procedures for better control of Air Force inventories at each base (11) (23) (24) (41) (42).

Aggregate Constraints.—Conditions in which aggregate constraints exist may result from either a deviation from the corporate objective to minimize costs or because of some limitation caused by the physical facility.

1. *Physical Constraints.*—Churchman determines constrained lot sizes for conditions in which either the warehouse space is limited, or machine time is limited with setup time consuming a considerable portion of the available machine time, or when both limitations exist (10, pp. 255-274). Magee obtains constrained lot sizes for conditions in which the production of products is made on a single facility in cycles with each product being produced once and only once each cycle; he also considers the condition in which machine time is limited with setup time consuming a considerable portion of the available machine time (36, pp. 310-315).

2. *Financial Constraints.*—Holt, Davis, and Karush determine ordering rules for the control of inventories when the capital invested in inventory must not exceed a specified value; each of these papers consider this problem under different conditions, which results in three different problems (15) (30) (33). There has recently been considerable research in the area of aggregate financial constraints upon inventories which is being performed under contract from the Office of Naval Research at Carnegie Institute of Technology (37) (50) (51) (52).

SPECIAL INVENTORY CONDITIONS

Relatively little work has been done in the field of economics in obtaining a connection between inventory control and economic theory. Recent attempts have been made to bridge this gap by deriving a relationship between inventory control and price theory (48) 56).

Bryan, Wadsworth, and Whitin have developed an inventory model for determining the quantity of inventory to hold at each of four stages of production in which the item is of a seasonal nature with variable demand (9). Vassian has developed a method which uses a form of feedback to adjust production and purchases by minimizing the variance of the inventory under certain conditions (46). Morse makes extensive use of queueing analysis in the study of inventories (39).

The basic types of inventory policies were first considered; next, the history of the developments in inventory control was summarized; and, finally, a tentative classification for inventory control theory was suggested with significant contributions being briefly outlined and referenced—first by either single item or aggregate item analysis, and second by the type of inventory policy. It is hoped that either an alternative plan or a modification to this plan will result from this attempt.

The role of the Industrial Engineer in inventory control is to understand the assumptions implicit in the

[1] A simpler version of this material appears in (34).

various inventory models and to be capable of evaluating when approximations can be made so that a proper application can be effected. The future will undoubtedly bring forth new and more precise solutions to the many variations of the inventory problem (of particular interest to the mathematician) and translations of these theoretical approaches to workable practical procedures (of particular interest to the Industrial Engineer).

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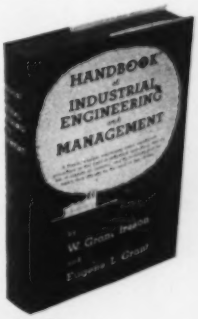

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Utilization Trends for Scientists and Engineers—Navy Style

by **ARTHUR L. SISSON, JR.**

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THE word, "trends," smacks of the need for graphs. The writer offers none. It also presents a word picture of something associated with statistics. Many of you may agree with the popular notion that the limbo of no "yesses" and no "no's" is the special province of the statistician—and of the politician. The writer is neither of these.

INTRODUCTION

Now that the introduction has been introduced, here is the Plan-of-the-Day: First, a statement of the essence of the Navy's Civilian Personnel Policy will be given. Then you will be offered some data in regard to the Navy's utilization of technical personnel. The writer will suggest the manner in which the technically-competent Naval Officer should, and usually does, work in consonance with his civilian associates for optimal progress. Claiming that "author's license" permits him to leave the parameters suggested by the title of this article, he will recount and comment upon a couple of things that are currently progressing that should be of interest to most scientists and engineers—certainly to the Industrial Engineers. Finally, he will recount a philosophical story.

PERSONNEL POLICY

The Honorable Richard Jackson, Assistant Secretary of the Navy for Personnel and Reserve Forces, stated to Congress in December of 1958 that the Civilian Personnel Policy of the Navy is "that vacancies will be filled only when (a) the work is essential, (b) the job cannot be abolished or consolidated with another job, and (c) the job cannot be filled by the reassignment of another employee."

DATA

The records of the Navy's Office of Industrial Relations show that total military and civilian employment within the Navy, in those activities where military and civilian employees work together, decreased 2.4 percent in the fiscal year ending, 31 June 1959—from 555,000 to 542,000. The decrease in civilian employment was 1 percent, while the decrease for the military was 3 percent. The total attrition rate for the year within the Continental United States was about 1½ percent. The attrition rate in manufacturing industries during the same period was almost three times as much.

Now for some data that are more specific to our topic, and not nearly so comforting to the Navy. For professional civilian employees in the critical occupational areas of science and engineering, the total change between the first and third quarters of fiscal year 1959 was a decrease of ½ percent. While the medical and biological sciences groups showed an increase of 6 percent, the engineering, physical sciences, and mathematics groups showed a decrease of 2 percent. A 6-month record of these data does not establish a "trend," but it would be of serious concern if the pattern continued.

Permit this one last piece of data: In order to study the oft-heard charge of "dual staffing," in November of 1958 the Navy reviewed over 28,000 management-type positions; 62 percent of these were civilian positions. The report did not show any situations of dual staffing. It did point out, however, that 151 positions should be converted from military to civilian and 16 from civilian to military.

DIVISION OF EFFORT

How should the responsibilities be divided between the military and the civilian technical population of the Navy? Can dual staffing be eliminated?

The Navy's technically-trained and experienced military and civilian personnel have a very high degree of mutual respect for each others' competence. It is recognized that the repeated exposure of the Naval Officer to the operational environment of the Fleet neatly complements the continuity afforded by the civilian scientist and engineer. In our Navy's management complex, however, the who-does-what factor can become critical. It boils down to the simple practicality that the officer should determine the *what* and the civilian should provide or create the *how*. Of course there must be knowledge of *what* and *how* by both parties, and this is the keystone of the mutual respect mentioned before. To this extent dual staffing does exist and must not be eliminated. Further consideration of dual staffing reveals that our Navy's two sources of technical competence must be able to "man the helm" for each other to cover situations such as travel and leave.

This complementary relationship, simple as it essentially is, sometimes seems difficult to convey in the civilian position descriptions. An extract from one engineering position description illustrates how this has been handled: "The civilian is responsible to the officer. The continuing work assignment is necessarily broad and essentially stated in terms of the objectives to be sought. The nature of the positions preclude detailed specifications. General spheres of operation will be established as appropriate to the background and experience of the officer and will be modified to reflect changing conditions and circumstances; the civilian is expected to anticipate or identify the necessity or desirability of action within the scope of the officer functions and to recommend, do, or direct such action as is appropriate."

ITEMS OF INTEREST

Perhaps we can get closest to home by recounting a couple of items that could affect us as Industrial Engineers in the foreseeable future.

After many years of work, the United States Civil Service Commission has proposed Position Classification Standards for Industrial Enginers. One of the salient features of this proposal is the Civil Service Commission's request for comments in regard to the necessity of giving Industrial Engineering candidates without an appropriate college degree a written, specific achievement test in Industrial Engineering. The specific achievement test presently required of them is in mechanical engineering. The Navy's position is that such a test is, in fact, a necessity. The proposed standards themselves point out that the positions covered are not limited to industrial production systems and plants. A discussion is provided of the distinctions between Industrial Engineers and mechanical, structural, and chemical engineers. Some of the distinctive contributions of operations researchers, management planners and analysts, and production and industrial specialists are also set forth. As you read this it is probable that the proposed standards discussed have been put into effect.

Second item: At the Naval Propellant Plant, Indian Head, Maryland, a statistical work sampling project covering engineering effort is underway. The purpose of this project is to objectively determine what the actual utilization is of a small group of engineers. The work situations being observed have been broadly categorized as:

1. Talking
2. Telephoning
3. Writing
4. Reading
5. Clerical
6. Transportation
7. Personal

Professional Civil Service engineers, internal to the propellant Plant, are making the work sampling study.

You are, no doubt, happy to learn that the work situations being observed at Indian Head don't include "thinking." As of this date, fractional-minute observations of thinking are not practicable. It would seem that the "clerical" categorization for the work of scientists and engineers would be a particularly sensitive one. In this era of automatic data processing and the timely control reports that can result, perhaps we are too often wrong in crying out against the "clerical" detail of filling out feeder forms for mechanized reports and the subsequent mark-up of the reports themselves. The claim is that such activity does not permit the exercise and utilization of the highest skills of technical personnel. Who can best and most quickly detect errors in such material? Aren't we among the first to "sing out" when a garbled mechanized report hits our desk? Some of us hardly raise an eyebrow when we consider a Weapons System that may have a 7-year development cycle, involve hundreds of man-years of effort, and involve the expenditure of several million dollars. It is patently reasonable that we be entirely cooperative and a little more tolerant of the "shake down" errors of some of our sophisticated management systems—properly designed, installed, and used, they can point out some of the standards that are necessary for the control of sophisticated engineering work.

EPILOGUE

Because of the increasingly complex problems that must be solved in today's, and tomorrow's, Navy, it is mandatory that its technical personnel remain creative and retain their sensible sense of humor. William H. Whyte, Jr.'s book, *The Organization Man*, gave a sober warning of the evils of hyper-conformity. The promised ending, the philosophical story, supplements Mr. Whyte's theme. It is the story of the processionary caterpillars:

> Processionary caterpillars feed upon pine needles. They move through the trees in a long procession, one leading and the others following—each with his eyes half closed and his head snugly fitted against the rear extremity of his predecessor.
>
> Jean-Henri Fabre, the great French naturalist, after patiently experimenting with a group of the caterpillars, finally enticed them to the rim of a large flower pot where he succeeded in getting the first one connected up with the last one, thus forming a complete circle, which started moving around in a procession, which had neither beginning nor end.
>
> The naturalist expected that after a while they would catch on to the joke, get tired of their useless march and start off in some new direction. But not so. . . .
>
> Through sheer force of habit, the living, creeping circle kept moving around the rim of the pot—around and around, keeping the same relentless pace for seven days and seven nights—and would doubtless have continued longer had it not been for sheer exhaustion and ultimate starvation.
>
> Incidentally, an ample supply of food was close at hand and plainly visible, but it was outside the range of the circle, so they continued along the beaten path.
>
> They were following instinct—habit—custom—tradition—precedent—past experience—"standard practice"—or whatever you may choose to call it, but they were following blindly.
>
> They mistook activity for accomplishment. They meant well—but they got no place.

The Use of Self-Paced Tasks for the Evaluation of Work Methods

by **JAMES W. BARANY**

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and **JAMES H. GREENE**

Associate Professor of Industrial Engineering, Purdue University

ONE of the most frequently encountered problems in human engineering is the determination of the effect of a given variable upon the efficiency with which a task can be performed. Three somewhat related measuring techniques have been used; namely, time study, physiological costs, and self-paced tasks. All three are based on the concept of efficiency which is defined as the ratio between the output and input of the system under observation.

PURPOSE OF TIME STUDY

The purpose of time study is to ascertain the time required by a normal, qualified, thoroughly experienced operator to perform a certain task while working under ordinary conditions at a pace which is representative of average. The time study analyst is trying to transform the performance of a given individual to an equal ratio scale which has been normalized with respect to a common level of operator effort; namely, an average speed of performance corresponding to a constant level of input. Therefore, the effectiveness of various work methods can be tested by means of a direct comparison of the output terms expressed in normal time units. The rationale for using time study data as the basis for comparing work methods rests on the assumption that productivity (rate of output) is a linear function of pace (speed of performance). This linear relationship is illustrated in Figure 1.

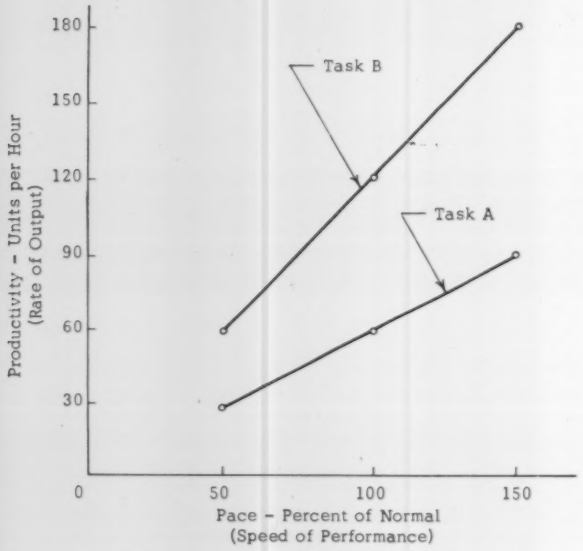

FIG. 1. The Linear Relationship between Speed of Performance and Rate of Output.

If two tasks, A and B, have output rates of 60 and 120 units per hour respectively for paces of normal performance, the number of units produced per hour for any performance level would be the product of the rate of output at normal pace multiplied by the actual pace level expressed in terms of a percentage of the normal pace. Therefore, an operator performing task A at a pace of 50 percent of normal would produce (0.50) × (60) or 30 units per hour; while an operator doing task B at the same pace would produce (0.50) × (120) or 60 units per hour. Similarly, the 150 percent performance level for task A and B would result in productions of 90 and 180 units per hour.

GOAL OF TIME STUDY

The goal of time study is to establish the normal production rates for the two tasks under investigation in such a manner that the time required by the normal operator to produce 60 units per hour for task A would be the same as that required to produce 120 units per hour for task B. Furthermore, it can be assumed that for the same class of work the performance time would be related to the physiological cost of the job. When the normal operator performs the two tasks at the same pace, and especially if both tasks involve the same muscle groups, the operator should be working at the same physiological exertion level in both instances. Therefore, the effectiveness of a proposed work method can be measured by determining its normal production rate which is the reciprocal of the normal-time value.

The utilization of time study data has many obvious drawbacks. The definition of time study is filled with a

series of nebulous terms such as "normal operator," "average pace," etc. One of the most controversial phases of the system is the subjective rating procedure required to normalize the observed operator's performance. For this reason, if none other, there has been a tendency to use criteria other than time in laboratory investigations concerned with the evaluation of the effects of external factors upon muscular work. Two substitute techniques have been used: direct measurement of various physiological input indices and self-paced tasks where the operator maintains a maximum speed of performance.

The first technique permits the comparison of the work outputs after having been adjusted with respect to equal units of physiological costs; or physiological cost estimates can be compared after they have been adjusted for equal units of output. The indices commonly used for evaluating the physiological costs of muscular activities are modifications in the heart rate, blood pressure, cardiac output, pulmonary ventilations, oxygen consumption, chemical composition of the blood and urine, body temperature, and rate of sweating (2). From their very nature, these studies necessitate rather elaborate equipment that often interferes with the performance of the experimental task.

In order to overcome the instrumentation problems posed by comparing physiological cost indices, the self-paced task technique has been adopted in some research. In this approach, the subject is instructed to perform the experimental tasks as rapidly as possible. The input term is assumed to remain constant for each task; namely, maximum exertion. Therefore, the work method which results in the largest output term is considered to be the most efficient. The validity of this line of reasoning is based upon the assumption that the proportionality of job difficulty remains constant for all speeds. This assumption is a direct result from the supposition that productivity is a linear function of pace. With reference to the previous example, the proportionality of job difficulty is the ratio between the outputs for task A and B at any one performance level. If this proportionality remains constant for all paces, a comparison of work methods at the maximum exertion point is as valid as comparisons based on data gathered at the normal performance level. Therefore, the need for the subjective rating procedure required to determine normal pace in a formal time study is eliminated. However, psychologists, physiologists, and Industrial Engineers have encountered situations which cast some doubt on the validity of these underlying assumptions.

Ryan in his discussion on muscular work maintains that operator effort is the proper index for measuring performance (5, p. 98). Operator effort is defined as the ratio of actual performance to the capacity or ultimate limit of performance for a particular individual at a given moment and under specific working conditions. Ryan goes on to give the following example:

> Suppose, for example, that the capacity of a given individual at a given time is 100 units per hour. He increases his rate of work from 50 to 60 units per hour, an increase of 10 percentage units of effort. Later he increases his rate once more from 60 to 70 units per hour, or by another equal step upon the arbitrary scale we have set up. Common observation, however, would make us suspect that the second increase is more difficult than the first, that the change in effort is greater in the second step than in the first. This would be an especially important factor when the performance varies close to the upper limit.

Barnes enumerates a number of studies conducted by physiologists to determine the most efficient pace for a certain job (1). Here, the most efficient pace is defined as the point at which the energy expenditures for a job, determined by oxygen consumption rates, are the least. The results of a few of these studies are: the optimum speed for wheeling a barrow is a normal brisk walk; walking on level ground is performed most economically at a rate of 3 miles per hour; and for carrying a load of 44 pounds, the most efficient pace is 2.6 miles per hour. These experiments indicate that every task has a most efficient pace. Therefore, the conclusions drawn from comparisons of the outputs obtained at the maximum pace level may be quite different from the conclusions drawn from comparisons of outputs near the most efficient pace level.

Industrial Engineers have also expressed some doubt about the effect of maximum pace of job difficulty. The percentage adjustments obtained from the Iowa experiments, which were performed at maximum pace, seemed to overestimate the allowance for job difficulty when applied in studies based on normal performance. This would indicate that job difficulty is not constant for all paces and therefore output is not a linear function of performance (4, p. 385).

In the light of the criticism of the underlying assumption for the use of maximum pace in analysis of the effect of various factors upon human performance, the purpose of this investigation was to test the hypothesis that the proportionality of the effect of job difficulty, ascertained by the physiological cost of the task, remains constant for all paces.

PROCEDURE

Subjects: Four male, right-handed, Caucasian engineering students served as experimental subjects. Two subjects were of medium build, while the remaining two subjects were of small and large build, respectively.

Apparatus and Task: The experimental tasks consisted of rotating a cast iron weight while seated in front of a circular track mounted on a work bench. The cast iron weights of five and ten pounds each were five inches in diameter, and 1 29/32 and 2 15/16 inches high. The internal and external edges of the track were constructed of three-quarter inch plywood nailed to an unpainted one-eighth inch plywood base. The layout of the experimental task is shown in Figure 2.

The physiological cost for rotating the weights was

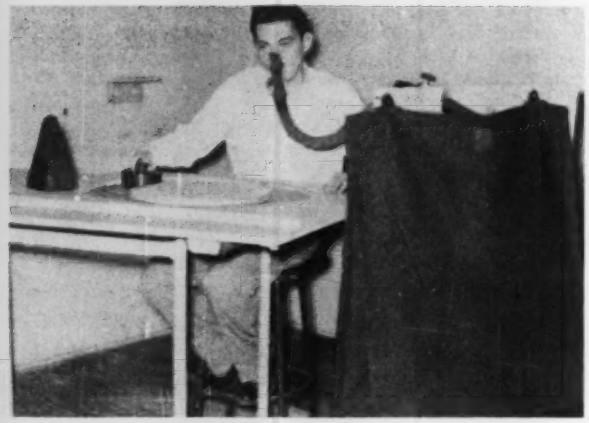

FIG. 2

determined by measuring the oxygen consumed during the test by means of the open loop method (3). While performing the tasks, each subject wore a nose clip and breathed through a respiratory valve assembly consisting of two one-way valves arranged in such a manner that he could inhale only atmospheric air and exhale only into a Douglas bag. The volume of the exhaled air in the Douglas bag was measured by a dry gas meter. This volume was corrected for temperature and barometric pressure. A sample of the exhaled air was analyzed on a Model F3 Beckman Oxygen Analyzer for oxygen concentration.

Routine: For at least one-half hour prior to the day of the first test, each subject practiced performing the tasks at four speeds while breathing through the respiratory valve assembly into the Douglas bag. Two operators had participated in experiments that utilized similar equipment, and it was felt that the remaining two operators could be trained within one practice session. For this reason, the effect of training was considered negligible.

A pilot study revealed that the operator had to maintain a speed of at least 24 revolutions per minute in order to be able to discriminate consistently between the resting and working metabolism. However, the average operator could not maintain a pace greater than 48 revolutions per minute with the ten pound weight for a work cycle of at least three minutes without experiencing excessive physiological fatigue. Therefore, the speeds of performance were set at 24, 32, 40, and 48 revolutions per minute. The operator controlled his speed in accordance with the audible tones of a metronome. A decimal-minute stop watch was used to record the elapsed time for the various activities.

The time of day at which the tasks were performed was not controlled other than having at least one hour elapse after the operator's last meal. Also, no attempt was made to have the operators perform on successive work days, and no operator performed the tasks twice in any one given day.

Each operator performed the two tasks twice for each pace. The order of the tasks was counterbalanced while the paces were randomized. The experiment consisted of a five minute rest period followed by a three minute work period plus a seven minute recovery period for each task.

RESULTS

The volumes and oxygen concentrations of the expired air samples were used to determine the caloric values for the resting and working periods from a nomogram prepared by J. B. de V. Weir (6). The resting metabolism was subtracted from the energy expenditure for the working cycle in order to obtain the cost for each task. These values are plotted in Figure 3 for each operator with the arithmetic means of the two trials per pace per task connected by straight lines.

The assumption that there is a negligible relationship between training and fatigue was checked. The percentage increase in energy expenditure for the second performance over the first performance was calculated for each test. A "Student's t" test revealed insufficient evidence to reject at the .05 level the hypothesis that the true average percentage increase is equal to zero.

An inspection of the curves in Figure 3 indicates that a large difference exists in the energy expenditures for the four operators. The energy expended by the smallest oprator, IV, at maximum pace is almost three times the amount spent by the largest operator, I. Also, the shape of the curves for operators I and II, who performed the ten pound task prior to the five pound task, is different from the curves for operators III and IV, who performed the tasks in the reverse order.

Next, the ratios of job difficulty for each operator at the four performance levels were determined by dividing

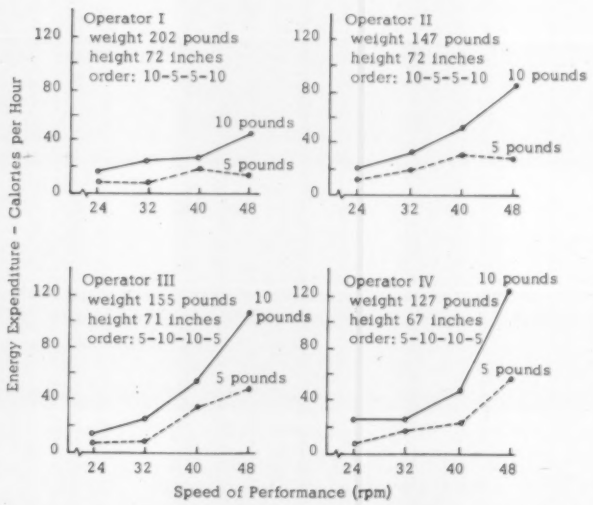

FIG. 3. The Average Energy Expenditure for Four Operators Rotating a Five and Ten Pound Cast Iron Weight at Four Different Speeds.

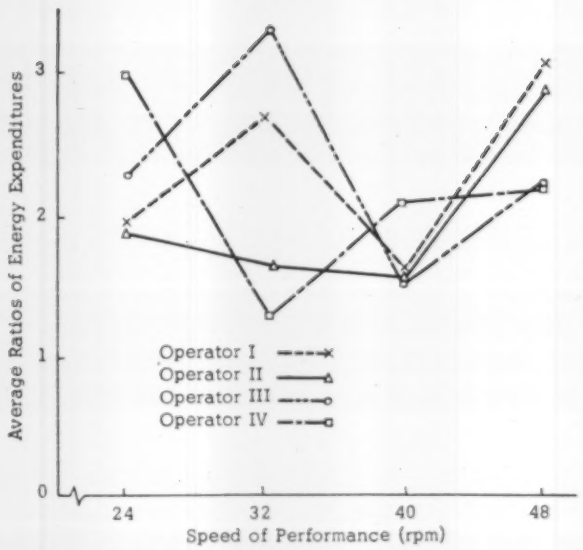

FIG. 4. The Average Ratios of Energy Expenditures for Four Operators Rotating a Five and Ten Pound Cast Iron Weight at Four Different Speeds.

the energy expenditure for the ten pound task by the expenditure for the five pound task. The average ratio for each operator is plotted in Figure 4. The assumptions of normality and independent sampling were made for the data. A Bartlett's test of homogeneity showed no reliable basis for rejecting the hypothesis that the samples came from equally variable normal populations. The results of an analysis of variance of the data are given in Table 1. The pace operator interaction term was significant beyond the .01 level. A Newman-Keuls analysis of the individual cell means revealed that three of the four operators had a pace at which the ratio of job difficulty was significantly greater than at the other three paces. For operators I and II this pace of greatest difficulty was at the maximum exertion level of 48 rpm. Of the other two, operator III found the 32 rpm. pace to contain the highest difficulty ratio; while operator IV did not exhibit any set pattern as far as changes in job difficulty were concerned.

DISCUSSION

When examining the curves for the energy expenditures of the two operators who performed the ten pound task prior to the five pound task, it becomes evident that the energy expended during the five pound task at the 48 rpm. performance level is less than that for the 40 rpm. level. This would indicate that if an operator performs the heavy task at maximum exertion first, the lighter task becomes physiologically easier. Needless to say, two observations are not enough to formulate any general principles.

Although the experimental results did not reveal a performance level at which the ratio of job difficulty is consistently greatest or least, there was evidence that each person would have one or more points at which the proportionality effect of job difficulty is significantly different from the others. Since the variability associated with physiological measurements is high, plus the fact that there is a variation connected with the individual operators and with the different orders of performing the task, any research which tries to pinpoint the levels of maximum or minimum job difficulty ratio must be based on a large number of observations. However, even with only two observations for four operators, there has been some evidence that the use of self-paced tasks might give different results than those obtained from time studies because job difficulty does not remain constant throughout the entire range of human performance. The next step would be to collect a large number of observations for typical industrial tasks for a large group of subjects in order to see if there is a practical significance among the results obtained at the maximum exertion level at normal performance.

SUMMARY

An attempt was made to determine whether the proportionality of job difficulty ascertained by physiological costs of performing two simple tasks which utilize the same muscle groups would remain constant at various exertion levels. The results indicated that a level of performances exists for an individual operator at which it is more difficult to proceed for the five pound task to the ten pound task than it is at some of the other pace levels. However, this exertion level appears to vary from operator to operator and possibly with the order in which the tasks are performed. Therefore, the over-all results were a cancellation of any significant main effect due to different paces when averaged over the four operators. However, these results are based on a total of 32 observations—four operators, four levels of performance, and two replications. The next step would be to see if a practical as well as a statistical difference exists between results obtained from self-paced tasks performed at the maximum exertion level and at speeds near what is commonly defined as "normal pace" in time study procedures.

TABLE 1
Analysis of Variance

Source of Variance	d.f.	M.S.	F. observed
Pace	3	1.32	1.42
Operator	3	0.15	1.35
Pace × operator	9	0.94	8.35*
Error	16	0.11	

* Significant at the 1% level

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Our Business Is Different

by **ELLIOTT DeFOREST**

Partner, Joseph B. Ward and Associates

"OUR BUSINESS is different." The management consultant becomes accustomed to hearing this from almost every new client. It is then his task to explain in a tactful way that in the course of exposure to many organizations in many fields of endeavor, he finds that all of us have the same basic problems of reaching the right market for our goods or services, of setting the right price, of making the best use of the funds available, of reducing waste and inefficiency, and above all, of getting people who can and will do the job the way it should be done.

DIFFERENCES

Let me introduce the subject of the small management consultant firm, then, by this original statement, "Our business is different!"

How is it different? Well, to begin with, it is essentially a field of small units. According to a 1955 survey made by a group of Harvard Business School students, there are about 5000 management consulting firms operating in the United States. These range from an international operation having a staff of about 600 down to numerous "lone wolf" entrepreneurs. The average firm is estimated to have a staff of about five persons.

Unlike manufacturing and merchandising operations, this business requires no inventory. The capital investment is, therefore, very small—only the cost of office furniture and equipment plus perhaps a small library of technical books. This no doubt explains the constant flow of new firms that appear, exist for a while, and then disappear. Like the new insurance salesman, the new consultant usually starts with a client or two from among his friends. When the list of friends is exhausted, he begins to find out that capital is needed after all—the capital to live until the flow of referrals and repeat business begins to keep him reasonably busy. If the consultant does a good job on the assignments he is given, the word will get around eventually, but it may take five years.

Another difference which follows from this is that the problem of a new consulting business can rarely be solved by intensive selling effort. Although there are a few high pressure operators who make things difficult for the legitimate consultant by their high-handed methods (which usually leave a trail of unhappy victims), the typical consultant is by nature a low pressure salesman. He prefers to concentrate on doing the best job he can on the work he has on hand, and hope that the world will beat the path to his door.

The state of business in general has a different effect on the consultant's volume of business. A mild recession may, in fact, be a stimulant as it makes client prospects more aware of the need for methods improvement. A depression deep enough to really hurt may put the consultant down to selling apples on the street corner, since no one will be able to afford him. Prosperity, on the other hand eliminates as a client the firm which makes money so fast that it comes to believe that it knows all the answers, but does make it possible for many alert concerns to undertake expansion and improvement programs. It is a truism in our office that most of our engagements come from the successful companies rather than the ones that are in trouble.

SIMILARITIES

While maintaining that "our business is different," I must admit that it has many problems common to all types of business. One of these is the accumulation of adequate cash reserves, in the face of our present tax laws. Another is the problem of high fixed overhead. With success, the temptation comes to acquire more expensive offices, and increase staff of high priced specialists. High fixed costs are the scourge of every business manager.

Diversification is just as important for the consultant as it is for the manufacturer. Especially in the Pacific Northwest, the number of prospective clients in any specialized field is limited. Furthermore, technical or market changes may close the door on a specific line of consultation forever. Since there is a limit to the number of fields

in which any single individual can hold himself out as an expert, the desire to diversify drives the consultant back into the dilemma of increasing his staff of high priced specialists.

This means that the consultant shares another problem which more and more companies are encountering—the effective utilization of higher-talented people. Higher-talent manpower cannot be treated to the same principles of uniformity that have been the foundation of personnel administration in recent years. They require different concepts of organization of work and of incentives.

HUMAN COMPONENT

Thus it comes back to the fact that in our business, a large part of the problem is people. In our client contacts, we find that a large part of their problem is people, too. So it is that although some case can be made for the fact that "our business is different," in the end we find that it is not very different after all.

This being the case, we should, as consultants, be deeply concerned about the people we bring into our organization. As a result of self-examination, we have established certain criteria.

1. Technical capability is a requisite almost too obvious to mention, except to stress the fact that in a small organization every staff member must represent the firm on his own at times, and must do it credit.

2. We do not seek people who duplicate talents now available to us. Rather, we hope for capabilities which will reinforce and expand what we already have.

3. Every staff member must carry his own weight, in the sense that he must produce his cost. He must be a self starter—able to occupy himself when not assigned to a client problem by study of new techniques, by research in some field of consulting service, or by making new contacts with potential clients.

4. He must be versatile—able to perform not only his own specialties but also to lend a hand with whatever problem is in the office.

5. The new man must be compatible. That is, he must be in agreement with our ethical standards and accept our concepts of professional service. Since the consultant is almost ipso facto an individualist, we recognize that one who meets all other requirements still may not be able to work in harmony with us, due to our peculiarities as much as his.

SUMMARY

The small consulting firm, then, finds that it has problems of money, marketing, men and management—just like almost everyone else. Only in not handling materials —in the sense of physical commodities—does he differ from the great majority of businessmen. He feels justified in saying, therefore, when owners and managers tell him that "our business is different" that while it may have some very individual characteristics, it also has the basic problems common to all businesses.

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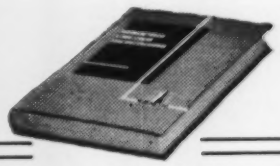

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Work Measurement in the Control Laboratory of Chemical Plants

by **ANDREW T. C. CHANG**[1]

Industrial Engineering Section, American Cyanamid Company, Bound Brook Plant

CONTROL laboratories are established to serve the manufacturing, sales, and research department, by testing the physical and chemical characteristics of raw materials, intermediates, and finished products.

The amount of time, equipment and reagents used for the tests constitute part of the cost of making the product. The cost may be reduced but not entirely eliminated. Herein lies a basis for improvement.

This acticle is intended to describe an approach to work measurement in control laboratories. It has been sucessfully applied at the Bound Brook Plant of the American Cyanamid Company. It is hoped that this same approach might be applied to other chemical plants and allied industries.

ULTIMATE GOALS

Work measurement in control laboratories will assist management in accomplishing the following objectives:

1. The attainment of the most economical level of service.
2. The provision of a satisfactory service for the operating units with the least expenditure.
3. The determination of manpower effectiveness as a possible basis for future improvement.
4. The determination of the optimum manpower requirements at a given performance level.
5. The minimization of overlapping or repetition among laboratories.
6. The exploration of the possibility of consolidating laboratories and the determination of the optimum manpower requirements under such conditions.
7. The achievement of the best arrangement for equipment and workload within the laboratory in order to simplify operations and to achieve the greatest efficiency.

In addition, it is expected that the data accumulated and the results so derived, from a work measurement study, can also be used for:

1. Future scheduling and programming of laboratory activities.
2. Future cost control.
3. Manning of new laboratories.
4. Incentive payment.

[1] The author wishes to thank Mr. L. E. Beiswanger, Director of Industrial Engineering of the Organic Chemicals Division, Mr. H. G. Kiggins, Jr., Supervisor of the Industrial Engineering Section, and Mr. H. J. Rodenberger, Manager of the Analytical and Control Laboratories, of the Bound Brook Plant, for their guidance and assistance.

Accomplishment of these objectives necessitates a complete understanding of the problems involved in the work measurement of a control laboratory.

PROBLEMS CONFRONTING WORK MEASUREMENT

As a service department, normal problems can be compounded in the control laboratories. Its workload, the necessity of shift coverage, and the complexity of the multiple tests involved, must vary directly with the activities of the manufacturing, sales and research departments.

Other problems in undertaking a work measurement study are the differing work habits of the technicians, the various types of apparatus used, the flexibility of arranging apparatus on a bench, and the variety of the tests performed.

Finally, a survey of literatures indicates there has been very little work done in this field in the chemical industry. Thus, to undertake such a task in an area where no useful precedent exists presents a formidable challenge to the Industrial Engineer. He must not only explore the problems involved but must formulate his own approach to deal with these problems.

THE FORMULATION OF A PROPER APPROACH

Time, effort, and the required reliability of data, constitute three major provisos in the process of formulating a suitable approach for work measurement in the control laboratory. The trio must be economically balanced without impairing the reliability of the results.

Regardless of the approach used, certain time values for the performance of each individual test in the control laboratory must be established. These time values, in turn, comprise the basis for any proposals made on manning, methods improvement, laboratory layout, consolidation or technicians' effectiveness. Thus, the first task in work measurement of control laboratories is to decide upon an optimum method of collecting time data.

Due to the vast number of dissimilar tests, ranging from the simple pH to the complicated determination of chlorine,[2] and to the varying frequencies of individual

[2] Complexity based on the relative number of steps involved in the test.

tests, any attempt to make a complete time study covering each individual condition would present an endless task and would unnecessarily prolong the project.

In view of the unrelated nature of the tests, no one single standard or standard time formula can be formulated to cover all cases.

The ease by which the portable laboratory apparatus and glassware may be moved about for convenience, the vastly different characteristics of samples and reagents, and upon occasion, the possible influence of a given process on the basic motion (such as weighing, titrating, stirring, etc.), all tend to illustrate why the predetermined time standard must be considered impractical. Furthermore, the time required for applying the predetermined time standard in this case does not warrant such an undertaking.

For a short-ranged evaluation, work sampling, based on the probability of normal curve distribution, does provide an over-all picture of the performance of the control laboratory. However, the summary drawn from such a study can furnish only limited data for formulating manning proposals. A change in the sample population, i.e., workload, types of tests, etc., will render meaningless the conclusions drawn from the work sampling study. The amount of time expended in taking the study and assembling the data will be totally wasted.

Therefore, with the known shortcomings of a standard time formula, of predetermined time standards, of work sampling and the time consuming waste of a complete time study, a new approach is needed and must be tailored to meet the requirements. Such an approach must be economically and qualitatively acceptable.

THE UNDERLYING PRINCIPLES

An examination of the elements involved in chemical testing in the control laboratories, reveals that the majority of the basic elements frequently repeat themselves in specific tests, and reappear as well among the various types of tests. The actual testing of a sample is merely a series of combinations of these basic elements. Thus, the function of setting up time values becomes a relatively simple task of recognizing the basic elements and compiling standard time values for each of these elements —the second task of work measurement in the control laboratory.

Each basic element is determined from a number of observations. The number of observations required for each basic element varies with the length of the elemental time, the frequency of its appearance and the range of variation among the values taken by time studies. It should be recognized that no two observation values will necessarily coincide. Therefore, it is unreasonable to assume that any one actual time observation should exactly equal the standard time for that value. A reasonable range of variations among the observations must be expected and accepted.

Furthermore, the standard time value determined in the foregoing manner should represent a much more valid measure of the basic elements observed, and a much more reliable measure of the individual variations in a test, than would be obtained from individual time studies.

It must also be recognized that there is no set, practical limit to which standard elemental times may be developed and refined. However, to be realistic, an engineer cannot delay until perfect standard elemental time values are available, or until perfect standard conditions have been established. Only the immediate utilization of the best available information can be the goal for better and more efficient performance in the laboratories.

Guided by these underlying principles a limited number of time studies should be taken and the time values rated regardless of the type of test or of the location. Depending upon the physical characteristics and the location of the workplace, all the rated time values for the same basic element may be grouped together. An average value is thus derived from the data available, for each basic element, and represents the time value for that basic element to date. Improvement on a basic time value can be made as more data are compiled.

The actual compilation of data for each basic element varies according to the engineer assigned to the task. However, a code number may be assigned to each basic element, thus making future cross references more convenient and systematic.

BASIC ASSUMPTIONS

The procedure, as stated previously, is simply one of determining the basic elements required in performing a task, and of then assigning a standard time value to each basic element. Since the standard is the goal in each case, it cannot be expected that every, or perhaps even any individual situation, will ever exactly meet the standard. Minor differences cannot be prevented. In order to minimize these variations for the purpose of uniformity, a number of assumptions are formulated. This formulation of assumptions becomes the third task of designing a proper approach for work measurement in the control laboratory.

1. All technicians should be properly instructed to perform the tests in a safe way. The company should provide safe working conditions and emphasize the development and maintenance of a high sense of safety-consciousness to the technicians.

2. Since the workload of the control laboratory is dependent upon the activities of the departments being served, samples should enter the laboratory at random and be tested on a first in, first out, basis. Special attention, however, should be given to those samples having a priority listing.

3. Each technician should have the skill of conducting two or more tests simultaneously, if the situation allows.

4. Idle time may be minimized by maintaining available backlogs to keep the technician occupied during interim periods.

5. The layout of the laboratory may be rearranged. Each technician should have his own bench supplied with enough glassware, necessary reagents, and frequently used apparatus. He works only

in his designated area. An average traveling time will be given to the technician for traveling between benches or other areas in the laboratory.

6. For reasons of simplicity, any variance of time values for a basic element caused by the flexibility of the arrangement of portable apparatus, reagent bottles, and glassware on the bench, will be assumed insignificant.

7. There is a significant difference in the time values, however, for manipulating various items of apparatus and glassware. For instance, the time needed for weighing a sample on the torsion balance is significantly different from that of weighing a sample on the analytical balance.

8. There is a significant difference in the basic elemental time for handling reagents or samples which are physically unlike. For example, the time required for weighing a powder sample to the exact weight differs from that needed to weigh a paste sample.

9. The standard derived from the basic elemental time indicates approximately the best procedure to follow under a given set of conditions. It should be regarded as a guide toward uniform action, against which actual performance can be evaluated and compared.

For the foregoing basic assumptions, as well as for all phases of a prospective laboratory study, it must be perfectly clear to the reader that safety rules and practices are paramount.

DETERMINATION OF THE STANDARD TIME PER TEST

The fourth task of work measurement in the control laboratory is the actual determination of the standard time per test. First, the best method of testing must be established. Then by recognizing the best sequence of the basic elements required to perform a test, based on the principles of Motion and Time Economy and by following the basic assumptions previously stated, the task of determining the standard time per test becomes merely the arrangement of basic elements and the assigning of the standard elemental times to each. Proper amounts of personal, delay, and fatigue allowance are then added to arrive at a final standard time per test, at any desired efficiency level. It is suggested that a three percent personal, a two percent delay, and a five percent fatigue allowance be added to the rated time to derive the productive capacity standard time per test.[3]

Standard groupings of basic elements, which can frequently be applied as a group, in the derivation of standard time per test, should be formulated as such whenever feasible. These groupings will give uniformity to the standards and reduce the time required for the establishment of standard time per test.

[3] Productive capacity represents work performed with a speed and effectiveness which is the best that an average, qualified and capable man, could be expected to sustain on an eight hour basis without injurious strain if he has an adequate amount of rest as required. Personal allowance is the time usually required for a technician to take a drink, wash up, and meet personal requirements. Delay allowance is the time allowed to cover minor uncontrollable delays. Fatigue allowance varies with the job performed. In general, sufficient fatigue allowance should be allowed to permit a normal technician to maintain a productive capacity performance level over a regular work period.

APPLICATION OF DATA ACCUMULATED

Based upon the standard basic elemental times and standard time per test, the manpower performance of a particular crew in a laboratory can be measured. Upon such information, suggestions can be made on the manning of the laboratory at any desired level of effectiveness.

The standard time per test can also be utilized as the basis for computing incentive payment. With the assistance of flow process charts, flow diagrams, man activity charts, and other tools used in the field of Industrial Engineering, proposals may be formulated on methodological improvements, laboratory layouts, work simplification, and the consolidation of laboratories.

In practice, the aforementioned approach has illustrated repeatedly the following three major advantages:

1. Provides faster development of standards and more accurate work standards.
2. The standard written automatically provides to the laboratory technicians the detailed description of the best sequence for performing a test.
3. It is easily understood and applied by other Industrial Engineers.

There is no set of rules or pattern for guiding one in the application of the data to the aforementioned fields. The actual utilization of the data available on hand will depend upon the knowledge, the ingenuity, and the judgment of the Industrial Engineer. The challenge is great but the potential savings should justify its undertaking.

The following is an example of the procedures used for applying standard basic elemental times and the standard time per test to a manning study of a control laboratory; it is not intended to present the intricate details but only to furnish the basic concept.

A SUGGESTED PROCEDURE FOR A MANNING STUDY

Assume for instance, that the coded standard basic elements have already been compiled and are available for use. A study of manning for the control laboratory is suggested to include the following steps:

1. The determination of the workload.
2. The determination of standard time per test.
3. The determination of manpower effectiveness.
4. The determination of manpower requirements.

DETERMINATION OF THE WORKLOAD

Past historical records should be used as a basis for determining the workload of the control laboratory. The period selected should be representative of the present level of activity and might also reveal any existing fluctuation of the workload. A period of four weeks to two months should be acceptable. Workload, types of tests, and their frequencies, should be recorded on a day, shift, and individual technician basis, for the purposes of de-

tecting daily fluctuations. In case there is no past record available, a form should be designed to record the necessary information for the period that follows.

DETERMINATION OF STANDARD TIME PER TEST

Based on the standard basic elemental times, the standard groupings, the laboratory instructions, and the basic assumptions on the application of the foregoing, the standard time per test can be synthesized for each individual test by an Industrial Engineer who is familiar with the laboratory operation.[4] Such a standard should give the best sequence for testing a certain sample. Necessary time studies should be taken for those tests which require the use of special apparatus. A sufficient amount of personal, delay, and fatigue allowance (i.e., ten percent) is then added to arrive at the productive capacity standard per test.

DETERMINATION OF MANPOWER EFFECTIVENESS

The standard time per test is applied to the frequency of each test to derive the workload of the period under survey. The credits so computed are then balanced against the available work hours of the technicians in determining manpower effectiveness. Consideration must be given to the difference in the number of available working hours per day between the regular day and that of the shift technicians.

The results of such computations will give the shift, daily, and average effectiveness of each individual technician and of the laboratory at a productive capacity effectiveness level, under a given set of conditions.

DETERMINATION OF MANPOWER REQUIREMENTS

Based on the available working hours per technician, the manpower requirements for a specific set-up, at any given effectiveness level, can be calculated. Proper consideration must be given to the effect of shift coverage and the possibility of consolidating laboratories.

Savings may result from the actual reduction of manpower in the laboratory, the reduction of overtime, or in increased output with the same personnel.

AN ACTUAL CASE

To this point I have merely described my approach to work measurement in control laboratories, and have suggested certain procedures for making such a study. I would like to present an actual case, in the last portion of this article, to factually illustrate my findings.

Laboratories *A* and *B*, set up to serve all of the production shops of a given multi-product manufacturing department, are distinctly located in separate buildings.

[4] It may be suggested that an Industrial Engineer and a laboratory technician be teamed for maximum results. The former's theoretical approach and the latter's practical experience should produce the optimum.

The manning of the two laboratories, prior to the study, was as follows:

Laboratory A	*Laboratory B*
1 Supervisor	1 Supervisor
1 Group leader	1 Group leader
6 Day technicians	5 Day technicians
3 Shift technicians (one/shift)	6 Shift technicians (two/shift)
1 Dishwasher	1 Dishwasher
12 Men	14 Men

A general survey was made of all major activities, within the two laboratories, to determine:

1. The scope of the proposed study on methods simplification and manning.
2. The time required for such a study.
3. The approximate cost of same.

A decision was made to study each laboratory independently. The data thus compiled would then be used, in a final study, to determine the feasibility of consolidating the two laboratories. It was also felt that immediate benefits could be realized if the studies were to be conducted on a step-by-step basis. This would allow corrective measures to be instituted, as certain weaknesses became apparent, rather than await the completion of the project and a final written report.

The general survey uncovered one costly feature immediately. In laboratory *A*, one hour per day was needed to standardize a solution (*Y*) used for daily testing (*X*). Concurrently the same standardization and testing took place in laboratory *B*.

To eliminate this duplication it was proposed, and accepted, to transfer all "*X*" tests to laboratory *A*. The move was accomplished without capital expenditure. The time, formerly required in laboratory *B* for the standardization, is being utilized for other productive work.

LABORATORY A

Laboratory logs, technicians' personal notebooks, and all other available records were analyzed to determine the types of tests made and the frequency of the tests. This was conducted over a specific number of working days. Workloads were recorded by day, by shift, and on an individual basis.

Based on standard element times, standard time groupings, and following prescribed laboratory instructions, a standard time, per test or per job, was synthesized. Special consideration was given to methods improvements and layout changes while assembling these data. Necessary time studies were taken and analyzed to determine a standard time for tests requiring special apparatus. All standard times, once resolved, receive an additional ten percent personal, fatigue and delay allowance to bring them to the one hundred percent level.

Standard times were applied for each test, in proper frequency, for the period under survey. Standard credits were then computed and balanced against available work

hours, to determine manpower effectiveness. Due consideration was given to the difference in the number of working hours available to the day and the shift technician. Seven and one-half hours were used for the former; seven hours for the latter.

At the 100% efficiency level, daily and average effectiveness of each technician was computed, based on present manning. It was found that the individual effectivenesses of the six day technicians was considerably below average. It was recommended that five day technicians be used for handling the workload of the present six men. Tests which had been run by the sixth technician were properly distributed to the remaining five technicians.

The absolute need for shift technicians (i.e., one man per shift), despite a comparatively light workload, precluded the opportunity to improve the shift coverage problem at this stage.

A manning proposal was offered to and accepted by management, resulting in the actual transfer of one technician to other work in the plant, at the same time providing satisfactory service.

LABORATORY B

The same procedure was used for the work measurement study of laboratory *B*. In the course of examining testing records, a number of statistical analyses were made to determine the validity of some of the tests. This later resulted in either the elimination of that test or the reduction of the frequency of making the test.

Two day technicians were transferred to other work in the plant as a result of the study. No improvement could be made on shift technicians because of the necessity of shift coverages.

THE FEASIBILITY OF CONSOLIDATION

Based on the workloads of both laboratories, the feasibility of consolidation was examined with regard to:

1. The space required versus space available, i.e., relocation and arrangement of equipment and benches.
2. The manpower requirements.
3. The capital expenditure involved.
4. The type of technicians needed.

It was concluded that with four men per shift, plus one supervisor, one group leader, 3 day men and one dishwasher, a total of 18 persons would be able to provide satisfactory service, with only a reasonable amount of capital expenditure. This change, using more shift technicians in lieu of day technicians, was found through experience to more effectively utilize the manpower.

The proposed manning, laboratory location, layout of equipment and benches were accepted and are presently being changed. The consolidation will result in the transfer of five technicians to other work in the plant, in addition to the three men previously mentioned in this article. The net effect of this study represents a 31% manpower savings

$$\left(\text{i.e. } \frac{3+5}{14+12} = 31\%\right).$$

In essence, this article attempts to do two things, first, to describe in detail an approach to suit a particular type of project and second, to show the advantages of engaging in such types of projects by chemical companies.

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A Regression Method for Determining Visual Inspection Times*

by GEORGE W. LADD

Associate Professor of Economics, Iowa State University of Science and Technology

and KEITH L. McROBERTS

Assistant Professor of Industrial Engineering, Iowa State University of Science and Technology

THIS ARTICLE reports the results of a successful experiment with the use of multiple regression to determine standard time data (1) (4). Multiple regression analysis is a rather common tool in Industrial Engineering, but is rarely used in the determination of standard times. It does have some points of similarity with a method discussed by Niebel (3). This presentation also presents a method for the graphic representation of man-hour requirements.

The first section presents the plant situation being studied. The next section discusses various procedures which could not be used to determine standard times, and explains why they could not. This is followed by a discussion of the multiple regression procedure used. Finally a graphic method of determining man-hour requirements from standard times is presented.

PROBLEM AND PLANT SITUATION

Quality inspection is a time consuming and often costly operation, frequently having a large potential for cost reduction through work simplification. In industries such as that of egg grading and cartoning, where the inspection function is one of prime importance, inspection costs become a major portion of the factory costs.

Plant managers in this industry have felt that there was a relation between the quality of incoming eggs and the number of man-hours required for inspection. The interdependency of grade and time becomes important as a determinant of standard crew size because of the seasonal variations exhibited by quality distributions. It has important implications for the formulation of policy as to the extent of a farm education and motivation program to raise the quality of eggs coming in to the inspection and cartoning, or assembly, plant.

In the research to be reported on here, one objective was to measure the relation of quality to labor requirements for the egg grading operation.

EGG GRADE DETERMINANTS

The determinants of the grade of an egg are its exterior and interior qualities. Exterior quality refers to the condition of the shell. Interior quality is determined by reference to three characteristics:

1. The size and condition of the air cell at the large end of the egg.
2. The condition of the white.
3. The position and condition of the yoke.

There are four U. S. Department of Agriculture grades, AA, A, B, and C, in addition to the undergrades. To illustrate the characteristics for which an egg grader must look in determining grade, the standards for AA and B grades are presented.

AA Quality

1. Shell—clean, unbroken, practically normal.
2. Air cell—⅛ inch or less in depth, practically regular.
3. White—clear, firm.
4. Yolk—well centered, outline slightly defined, free from defects.

B Quality

1. Shell—clean, unbroken, may be slightly abnormal.
2. Air cell—⅜ inch or less in depth; may show movement not over ⅜ inch; if not over ⅝ inch, may be free.
3. White—clear, may be slightly weak.
4. Yolk—may be off center, outline well defined, may be slightly enlarged and flattened, may show definite but not serious defects.

EGG INSPECTION PROCESS

In the plants studied, all eggs were machine sorted by size prior to delivery by conveyor to the egg grading stations.

* Based upon Journal Paper, Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa, Project No. 1369, Center for Agricultural and Economic Adjustment cooperating.

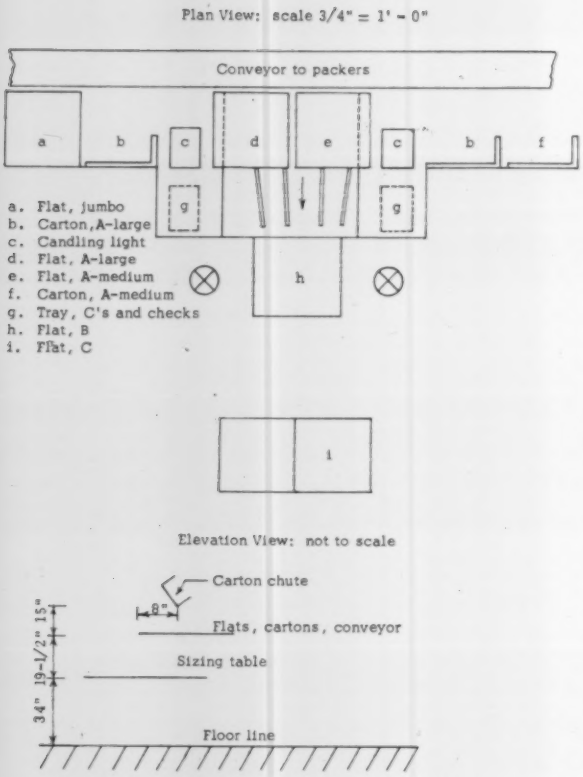

FIG. 1. Typical Semiautomatic Sizing Machine Workplace Layout

The inspection, or candling, consists of the following elements:

a Pick up two eggs in each hand.

b Examine the shell exterior in a light beam directed downward onto a conveyor.

c Inspect the interior of the egg by examining the shadow detail created by holding the egg in front of a light beam directed toward the candler.

d Decide the grade class by mental comparison to a set of standards established by the United States Department of Agriculture. (Elements *c* and *d* occur simultaneously and will be referred to as element *c-d*.)

e Dispose of the egg into a 1-dozen consumer carton or 3-dozen bulk pack depending on the weight and grade classification.

f Dispose of filled cartons or bulk pack flats to a moving conveyor.

g Position new cartons or bulk pack flats to receive inspected eggs.

h Record a tally of the numbers of eggs received by grade for each producer lot inspected.

Figure 1 shows a typical candling station layout.

FIXED TIME ELEMENTS

Some of these elements can be considered constant with respect to egg quality. The pickup *a*, disposal *f*, and positioning *g* all tend to be constant by virtue of the fact that the distances in each of these elements remain essentially constant. Some variation in distance might occur in the disposal of cartons and bulk pack flats. With the use of MTM standard data, it was determined that the time differentials were negligible and would have no significant effect on manpower requirements.

Element *h* is not a function of quality of eggs being handled, nor of size of the farmer's delivery.

Standard times for elements *f*, *g* and *h* were determined by regular stop watch procedures. Standard time for element *a* could not be determined in this way because of its short duration and because there is no distinct end point separating the performance of element *a* from the performance of element *b*. Standard time for *a* was determined in the same way as standard times for elements *b*, *c-d*, and *e*.

VARIABLE ELEMENTS

The question to be answered has now been narrowed down to this. Does the time required to perform elements *b*, *c-d*, and *e* vary with the quality of the egg being handled? To determine the answer and to determine standard time for element *a*, several procedures were considered and rejected. The short duration of some of the elements and the lack of definite end points separating *a* and *b* precluded the use of the common stop watch timing procedures.

LABORATORY ANALYSIS

Because of the mental decision processes involved in elements *b* and *c-d*, the determination of inspection time by grade does not lend itself to laboratory analysis.

FILMING

The process of filming the operation at normal work places and analyzing the film for elemental times could not be used. The egg grading areas are dimly lighted inasmuch as the interior inspection of the egg is based on shadows cast by the air space, yolk and white when the egg is held in front of a narrow directed light source. The additional light required for filming would have made it impossible for the inspectors to determine the grade of the eggs.

NIEBEL GROUPED ELEMENTS PROCEDURE

The present problem is closely related to one discussed by Niebel. He writes (3, p. 284).

> Sometimes because of the brevity of individual elements, it is impossible to measure their duration separately. It is possible to determine individual values by timing groups collectively and using simultaneous equations to solve for the individual elements.

In the example he uses to demonstrate the procedure, there are five elements. Let us label these elements *a*, *b*, *c*, *d*, and *e* and let T_i, $i = a, \ldots, e$, represent the time required for the performance of element *i*. He combines

the elements into five groups of three and times the groups to obtain the observed times t_i.

$$\begin{aligned} T_a + T_b + T_e &= t_a \\ T_b + T_c + T_d &= t_b \\ T_c + T_d + T_e &= t_c \\ T_d + T_e + T_a &= t_d \\ T_e + T_a + T_b &= t_e \end{aligned} \qquad \text{Eq. 1.}$$

He then solves the five simultaneous equations for the five unknowns T_i.

There were several reasons why this procedure was not used. Consideration of this procedure, however, led to the selection of the method adopted.

It is now necessary to take a somewhat closer look at the problem. There are 10 elements that must be studied. Each of the elements b, combined c-d, and e must be subdivided into three elements, one for A and AA eggs, one for B quality eggs, and one for C and undergrade eggs. (It was necessary to combine A and AA eggs since the plants studied did not differentiate between them; C and undergrade eggs were combined since the plants handled these two grades in the same way.) These 9 plus element a constitute the 10 elements. The solution of 10 simultaneous equations for 10 unknowns is certainly possible. The procedure chosen, however, requires the solution of only four simultaneous equations for four unknowns.

The lack of a definite end point separating elements a and b make it difficult to obtain satisfactory groupings of the elements.

Another reason for not using the Niebel method lies in the nature of the question being asked, "Is there really a difference in the amount of time required to handle various grades of eggs or are the small differences observed in our sample of plants really due to random errors of sampling so that the differences would disappear if we had a sufficient large sample?" Niebel's method will not answer this question; it will only yield sample estimates of the average time required for each element.

MULTIPLE REGRESSION

The procedure chosen has two points in common with the Niebel procedure. It involves grouping elements and it utilizes simultaneous equations. It is a statistical analysis since a statistical problem existed—drawing conclusions or making inferences from sample data.

Multiple correlation or multiple regression analysis is a recognized Industrial Engineering tool. Recently Canning presented an interesting application of multiple regression to estimate man-hour requirements (1). The procedure used in the present study was a special kind of multiple regression known as homogeneous regression.

In spite of the fact that multiple regression is well covered in the literature, the computational procedure will be briefly outlined, followed by an outline of the homogeneous regression method. In this way, the reader can conveniently compare the two.

MULTIPLE REGRESSION

This deals with the problem of attempting to estimate or predict a dependent variable Y by a function of independent variables or predictors, X_i. The linear estimating equation is

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \cdots + b_kX_k \qquad \text{Eq. 2.}$$

in which $\hat{Y}$ is the estimated value of Y, and the b_i are the partial regression coefficients obtained from the solution of k simultaneous equations. The estimation of the b_i commonly proceeds by the use of the transformed variables

$$y = Y - \overline{Y},\ x_i = X_i - \overline{X}_i \qquad \text{Eq. 3.}$$

which are deviations about the means, $\overline{Y}$ and $\overline{X}_i$. The b_i, $i \geqslant 1$, are estimated by the use of these variables and b_0 is estimated from

$$b_0 = \overline{Y} - b_1\overline{X}_1 - b_2\overline{X}_2 - \cdots - b_k\overline{X}_k. \qquad \text{Eq. 4.}$$

To obtain the estimated b_i, the first step is to compute the symmetric matrix of corrected sums of squares and cross products.

$$\begin{bmatrix} \Sigma x_1^2 & \Sigma x_1x_2 \cdots \Sigma x_1x_k \\ \Sigma x_1x_2 & \Sigma x_2^2 \cdots \Sigma x_2x_k \\ \cdot & \cdot \quad \cdot \\ \cdot & \cdot \quad \cdot \\ \Sigma x_1x_k & \Sigma x_2x_k \cdots \Sigma x_k^2 \end{bmatrix} \qquad \text{Eq. 5.}$$

In each case, the range of summation is from 1 to N, where there are N items in the sample. This matrix is inverted, e.g., by the Doolittle method, to obtain the symmetric inverse matrix whose elements are

$$\begin{bmatrix} c_{11} & c_{12} \cdots c_{1k} \\ c_{21} & c_{22} \cdots c_{2k} \\ \cdot & \cdot \quad \cdot \\ \cdot & \cdot \quad \cdot \\ c_{k1} & c_{k2} \cdots c_{kk} \end{bmatrix}; c_{ij} = c_{ji}. \qquad \text{Eq. 6.}$$

The regression coefficients are computed from

$$b_i = c_{1i}\,\Sigma\, x_1y + c_{2i}\,\Sigma\, x_2y + \cdots + c_{ki}\,\Sigma\, x_ky. \qquad \text{Eq. 7.}$$

The coefficient of multiple determination is computed as

$$R_y^2 = \frac{b_1\,\Sigma\, x_1y + b_2\,\Sigma\, x_2y + \cdots + b_k\,\Sigma\, x_ky}{\Sigma\, y^2}. \qquad \text{Eq. 8.}$$

The standard errors of the coefficients are

$$s_{b_i} = \sqrt{\frac{c_{ii}(1 - R_y^2)\,\Sigma\, y^2}{N - k - 1}}. \qquad \text{Eq. 9.}$$

The covariances between the coefficients are

$$s_{b_ib_j} = \frac{c_{ij}(1 - R_y^2)\,\Sigma\, y^2}{N - k - 1}. \qquad \text{Eq. 10.}$$

To test the null hypothesis $R_y^2 = 0$, compute the F test

$$F = \frac{R_y^2(N - k - 1)}{(1 - R_y^2)(k + 1)}. \qquad \text{Eq. 11.}$$

To test the null hypothesis $b_i = 0$, compute the t test

$$t_i = b_i / s_{b_i} . \qquad \text{Eq. 12.}$$

To test the null hypothesis $b_i - b_j = 0$, compute

$$t_{i-j} = \frac{b_i - b_j}{\sqrt{s_{b_i}^2 + s_{b_j}^2 - 2s_{b_i b_j}}} . \qquad \text{Eq. 13.}$$

HOMOGENEOUS MULTIPLE REGRESSION

This is concerned with the use of estimation equations of the form

$$\hat{Y} = b_1 X_1 + b_2 X_2 + \cdots + b_k X_k . \qquad \text{Eq. 2a.}$$

In Eq. 2., when all $X_i = 0$, $\hat{Y} = b_0$. In Eq. 2a., when all $X_i = 0$, $\hat{Y} = 0$. Thus, Eq. 2a. constitutes a special case of Eq. 2. and is an appropriate specification whenever the regression plane is expected to pass through the origin.

To compute the estimates in homogeneous regression, the untransformed variables Y and X_i are used. The first step is to compute the symmetric matrix of uncorrected sums of squares and cross products:

$$\begin{bmatrix} \Sigma X_1^2 & \Sigma X_1 X_2 & \cdots & \Sigma X_1 X_k \\ \Sigma X_1 X_2 & \Sigma X_2^2 & \cdots & \Sigma X_2 X_k \\ \vdots & \vdots & & \vdots \\ \Sigma X_1 X_k & \Sigma X_2 X_k & \cdots & \Sigma X_k^2 \end{bmatrix} \qquad \text{Eq. 5a.}$$

Invert this matrix to obtain the symmetric matrix

$$\begin{bmatrix} C_{11} & C_{12} & \cdots & C_{1k} \\ C_{21} & C_{22} & \cdots & C_{2k} \\ \vdots & \vdots & & \vdots \\ C_{k1} & C_{k2} & \cdots & C_{kk} \end{bmatrix} \qquad \text{Eq. 6a.}$$

Lower case c is used in Eq. 6. and capital C in Eq. 6a. to emphasize that the former are computed from $\Sigma x_i x_j$ and the latter from $\Sigma X_i X_j$. To obtain the homogeneous regression coefficients, use Eq. 7a.

$$b_i = C_{1i} \Sigma X_1 Y + C_{2i} \Sigma X_2 Y + \cdots + C_{ki} \Sigma X_k Y . \qquad \text{Eq. 7a.}$$

The coefficient of homogeneous multiple determination is computed as

$$R_Y^2 = \frac{b_1 \Sigma X_1 Y + b_2 \Sigma X_2 Y + \cdots + b_k \Sigma X_k Y}{\Sigma Y^2} . \qquad \text{Eq. 8a.}$$

The standard errors and covariances are computed as

$$S_{b_i} = \sqrt{\frac{C_{ii}(1 - R_Y^2) \Sigma Y^2}{N - k}} , \qquad \text{Eq. 9a.}$$

$$S_{b_i b_j} = \frac{C_{ij}(1 - R_Y^2) \Sigma Y^2}{N - k} . \qquad \text{Eq. 10a.}$$

The F test is computed as

$$F = \frac{R_Y^2 (N - k)}{(1 - R_Y^2) k} . \qquad \text{Eq. 11a.}$$

The null hypotheses are tested as before, using

$$S_{b_i} \text{ and } S_{b_i b_j} .$$

STANDARD TIMES FROM HOMOGENEOUS REGRESSION

As pointed out, the work situation being studied consists of 10 variable elements. Before applying homogeneous regression procedures, these were combined into the following four elements:

1. Pickup of two eggs in each hand.
2. Elements *b*, *c-d*, and *e* performed on an A or AA quality egg.
3. Same elements for a B grade egg.
4. Same elements for a C grade or undergrade egg.

The data were accumulated by observing a certain number of eggs being handled and recording the time involved, the number of pickups, and the number of each grade resulting. The number of eggs per observation varied from 4 to 20 due to operating and observation conditions but averaged approximately 16 per observation band. These data were obtained from 14 different candlers at five different assembly plants all employing semiautomatic weighing machines. A total of 332 observations was made as a basis for analysis.

Each of the 332 observations consisted of observed values for the variables:

X_1 = number of pickusp.
X_2 = number of A or AA quality eggs.
X_3 = number of B grade eggs.
X_4 = number of C and undergrade eggs.
Y = total time required for handling the indicated number of eggs. (The number of eggs equals $X_2 + X_3 + X_4$.)

The relation between these observations can be represented by Eq. 2a., since $Y = 0$ if all four $X_i = 0$. The regression coefficients b_1, b_2, b_3 and b_4 represent the average time required for the performance of the respective elements.

The application of the homogeneous regression computational steps yielded the results in Table 1. The results show that it can be concluded that the amount of manhours required to handle a given volume of eggs is a func-

TABLE 1

Homogeneous Regression Estimates for Time Requirements

	Elements (independent variables in regression analysis)			
	X_1 (Pickups)	X_2 (A grade)	X_3 (B grade)	X_4 (C and undergrades)
Time T_i (or b_i), minutes	0.0230	0.0177	0.0224	0.0338
t test, t_i	3.728	4.338	6.268	1.262
Confidence level	99%	99%	99%	80%
$R^2 = 0.942$ F = 1314.47				
	Tests of significance of differences			
	$\lvert b_2 - b_3 \rvert$	$\lvert b_2 - b_4 \rvert$	$\lvert b_3 - b_4 \rvert$	
t test, t_{i-j}	2.649	3.126	5.544	
Confidence level	99%	99%	99%	

tion of the percentage distribution of the various grades of eggs.

A LIMITATION ON THE HOMOGENEOUS REGRESSION METHOD

If one independent variable or predictor is linearly dependent on other independent variables, as

$$X_i = \alpha_j X_j + \alpha_r X_r + \alpha_s X_s + \cdots, \qquad \text{Eq. 14.}$$

none of the regression coefficients can be computed. In this case, Eq. 5. or Eq. 5a. is a singular matrix, i.e., its determinant equals zero, and the inverse Eq. 6. or Eq. 6a. does not exist. In the egg candling situation, each element b, c-d, and e occurs exactly once for each egg, $X_b = X_{c\text{-}d} = X_e$. Because of this linear dependence, regression cannot be used to estimate standard times for the separate elements but can be used to determine time for the combined element b-c-d-e.

If candlers always performed element a in exactly the way described, it would always be true that

$$X_1 = \tfrac{1}{4}(X_2 + X_3 + X_4) \qquad \text{Eq. 15.}$$

and the standard times could not be determined from regression analysis. Fortunately, however, at times an operator would pick up less than four eggs. For example, at the beginning or end of a lot, there might be only two or three eggs available for pickup. Therefore, Eq. 15. does not hold exactly for every observation and b_i can be estimated by regression analysis.

In our work, we combined elements b-c-d-e. There is a recognizable end point separating d and e. It would be possible to estimate an average time for e and for combined element b-c-d in either of three ways.

1. Proceed as we did to determine standard times for the combined element b-c-d-e. Determine MTM times for element e for each grade of egg and then subtract these times from the average times for b-c-d-e for each egg grade.

2. Observe the same total time as in 1. and again estimate MTM times for element e. In the regression analysis, use as Y the total observed time minus $b_{e_i}X_{e_i}$ where X_{e_i} = the number of occurrences of element e with an egg of grade i and b_{e_i} is the MTM time for e_i.

3. Determine average time for e by MTM analysis. Observe total time for elements a through d and use homogeneous regression to estimate time requirement for a and for b-c-d.

These three examples give some idea of the flexibility of regression analysis and of how regression results can be combined with other average time data.

MAN-HOUR REQUIREMENTS FOR INSPECTING 100 CASES OF EGGS

The results from the homogeneous regression analysis can be added to the results for the fixed time elements to determine the amount of labor required to handle a given volume of eggs with various percentage distributions among the different grades and with differing average producer lot size. The labor requirements can be estimated from the equation.

$$\hat{Y} = [0.0230X_1 + 0.0177X_2 + 0.0224X_3 + 0.0338X_4 + 0.0812X_{fc} + 0.1950X_{ff} + 1.7140X_h]1.15 \qquad \text{Eq. 16}$$

The coefficients of X_1 through X_4 are the homogeneous regression coefficients estimated before. X_{fc} is the number of occurrences of combined element f-g with a carton; X_{ff} is the number of occurrences of f-g with a flat; X_h is the number of occurrences of element h. The coefficients for these latter three variables are the average times for the fixed time elements determined by conventional stop watch timing procedures. The multiplier of 1.15 is used to obtain a 15 percent allowance for fatigue, delay and personal time.

Egg grading plant managers frequently think in terms of costs or man-hours per 100 cases. One hundred cases contain 36,000 eggs. This gives $X_1 = 9{,}000$. The values of X_2, X_3 and X_4 are obtained by multiplying 36,000 by the specified percentages of AA and A eggs, of B eggs, and of C or undergrade eggs. The value of X_{fc} is one-twelfth of the total number of cartoned eggs. In most plants, only A and AA quality eggs were cartoned; thus,

$$X_{fc} = \frac{1}{12} X_2$$

would apply to most plants. X_{ff} is one-thirty-sixth of the sum of X_3 and X_4. The value of X_h is obtained by dividing 100 by the average number of cases per farmer delivery.

In order that plant managers can conveniently determine the time required for inspection of any combination of grades for varying lot sizes in total quantities of 100

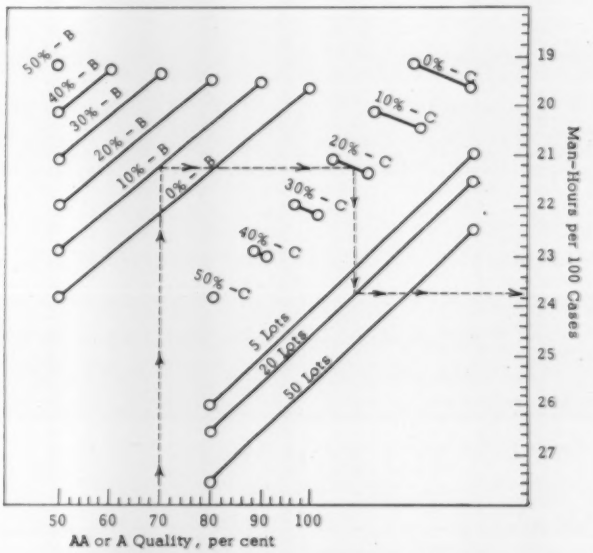

FIG. 2. Determination of Candling Time per 100 Cases with Varying Grade and Lot Size.

cases, Figure 2 has been developed. In this chart, the assumption that AA and A grade are cartoned and the remainder bulk packed has been maintained. The broken line path through the chart illustrates its use under the conditions of 70 percent AA or A quality, 10 percent B quality, 20 percent C quality, and 20 lots of 5 cases per lot. Beginning with the 70 percent AA or A quality, the line moves vertically to the 10 percent B line and is reflected at a 90° angle to the 20 percent C line. It is again reflected 90° to the 20 lot line and finally to the scale at the right margin indicating the total time requirements. Under these conditions, the computed time is 23.76 hours and graphically the time requirement is 23.7 hours.

SUMMARY

This report has presented a successful application of homogeneous multiple regression to the determination of standard times. In the situation studied, this technique could be applied whereas more common techniques could not. Standard times determined by regression analysis were combined with other standard times. A means of translating standard times into a graphic determination of man-hour requirements was presented.

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Labor Cost Analysis by Work Sampling in the Small Business

by **J. D. ISHERWOOD**

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THE small businessman is frequently at a disadvantage with respect to the larger organization. He is unable to afford a full time cost accountant, and is even less likely to be able to hire a full time Industrial Engineer. The benefits that accrue to any business employing these professional men are consequently denied him. Cost accounting is delegated to one of the office staff, and is often performed in such a manner as to be satisfactory for income tax purposes, and little else. Industrial Engineering, if any is attempted, is the province of the owner or one of his employees, clearly on very much of a part time basis. "Improvements" in methods, working conditions, and the like are mainly on a trial and error basis, and an "improvement" may turn out to be a "pig in a poke."

Management practices such as outlined would not be tolerated by the present day factory manager. In the nonmanufacturing industries, however, particularly the agricultural industries, the small size of many of the individual businesses makes it difficult or impossible to justify the expense involved in keeping detailed records of labor cost. To employ a consultant to make a comprehensive study of the entire organization is not a solution that will readily sell itself to the owner-manager. The problem is to get cost analysis details and to evaluate job procedures quickly without employing additional help.

This paper outlines an application of a work sampling technique, which may be used to provide a convenient and straightforward solution to this problem. A competent member of the office staff can be readily trained as an observer. Moreover the method does not require long periods of continuous observations, which is all the more attractive if observing is to be a part-time job.

Part time observation over a period of several months will, in general, lead to a more reliable estimate of the fraction of time devoted to an activity, than would the same number of hours of observation concentrated in a few consecutive weeks. With a two hour per day schedule the salient points of labor cost analysis could perhaps be made available after about two weeks for an organization of 50 employees or less. Variations from week to week, month to month, and in particular seasonal variations will, however, not be measured if observations are confined to a single two or three week period.

Rosander and others have successfully applied work sampling to 350 office workers in a large organization to obtain activity and cost analyses (5). The activity of each employee was determined by providing data sheets which the employee completed, anonymously, at a given random time instant. The random times were called to the supervisor by telephone. The technique of data collection is well suited to sample large numbers of office personnel but is inappropriate for the small industrial firm.

The procedure outlined below is based on observations made during a study of California wholesale plant nurseries, particularly those growing plants in containers (pots, cans, etc.) It will be clear that although details in both the text and the figures refer specifically to this industry, the procedure is equally valid for any small business.

APPLICATION TO THE PLANT NURSERY INDUSTRY

Plant nursery sales approached $400 million nationally and $32½ million in California according to the 1954 Census of Agriculture. Labor accounts for a sizeable fraction of the grower's costs, and in view of rising labor costs, the nursery industries need to consider, more carefully than in the past, both mechanization of certain operations, and the utilization of the existing labor force to the best possible advantage. The present trend in nursery operations, as in the field of agriculture in general, is toward larger organizations with the capital to finance and the business volume to make good use of machinery. However, a basic difficulty in most nurseries at present, even the larger ones, is the lack of even simple cost accounting records to enable the nursery owner to determine the percentage of time that is actually spent on different operations. In order to estimate the labor cost on a particular task a fixed interval work sampling procedure has been applied successfully to nursery operations.

SAMPLING PROCEDURE

The procedure adopted differs from random work sampling only in the selection of a suitable fixed time interval. This is easily established by the observer walking through all work areas, selecting a route that will enable him to observe all employees. A time interval may then be chosen which will allow adequate time for actual observation trips. Thirty minutes were found to be more than sufficient for an observation trip in the nursery study, and a round of observations started every half hour. All employees should be observed on each trip and a mark entered in the appropriate job classification category as shown in Figure 1.

SHEET NO. 1

COMPANY NAME _____ DATE _____

TIME START 7 30 AM ADDRESS _____

TIME FINISH 4 0 PM NO. OF MEN 20 OBSERVER _____

TOTAL HOURS _____ NO. OF WOMEN 22

OPERATIONS	TALLY	TOTAL
MAKING CUTTINGS	𝍸 𝍸 𝍸

COST BREAKDOWN TALLY SHEET

SHEET NO. 1

COMPANY NAME _____ DATE _____

TIME START _____ ADDRESS _____

TIME FINISH _____ NO. OF MEN 20 OBSERVER _____

TOTAL HOURS _____ NO. OF WOMEN 22

OPERATIONS	ROUND NO. 1					ROUND NO. 2				
	CENTS PER MINUTE			TOTAL		CENTS PER MINUTE			TOTAL	
	2	3	4	SCORE	CENTS	2	3	4	SCORE	CENTS
MAKING CUTTINGS	////			4	8	//			2	4
POTTING	///		/	4	10	////		//	7	18
POTTING UP			/	/	4		//	/	3	10
WATERING (HOSE)		/		/	3				0	0

FIG. 2. Sample Data Sheet for Scoring Observations by Wage Brackets.

This simple approach will rarely be sufficiently accurate when the number of people engaged in potting varies and the wage rates are not alike. A refinement may be added by scoring the original data sheets in terms of wage rates. The type of business firm under discussion is small enough that one of the supervisors or payroll staff would know both each individual and the latter's wage bracket. This is not difficult when 90% of the women fall in one bracket and perhaps 80% of the men in another.

Part of a suitable score sheet is given in Figure 2. Only the potting figures shown will be used as an example. During the first round of observations 3 employees at 2 cents per minutes and 1 employee at 4 cents per minute were engaged in potting, making a total of 10 cents per minute for the potting group. Three other rounds also showed a 10 cent total, making a total of four in the 10 cent category in Figure 3. The frequency distribution of group costs in cents per minute for all fifty observation trips is shown in Figure 3.

From the data given the mean cost can be calculated

$$\bar{C} = \frac{\sum_{i=1}^{n} F_i C_i}{n} = \frac{712}{50} = 14.24 \text{ cents/minute.}$$

where n is the total number of rounds.

The variance (2) is given by

$$s^2 = \frac{\sum_{i=1}^{n} F_i C_i^2 - n\bar{C}^2}{n - 1}$$

$$= \frac{11256 - 50(14.24)^2}{49}$$

$$= 22.8 \text{ cents per minute.}$$

The standard deviation of the mean cost is then

$$s_{\bar{c}} = \frac{s}{\sqrt{n}} = \frac{4.78}{7.07} = 0.675 \text{ cents/minute.}$$

Therefore, with a probability of twenty to one, the mean cost will lie between 14.24 ± 1.35 cents per minute. It will be noted that the simple procedure using the fraction of time computed for the potting operation gave a very similar answer (12.6 cents). This is due to the homogeneity of the potting group (in terms of wage rates) in this nursery. Similar calculations for all other operations will enable the costs for each to be determined.

DISCUSSION

Work sampling at random times requires that a code be devised to convert random numbers into the time of day and the day of the week. The adoption of equally spaced starting times simplifies the procedure. It is of course necessary to select starting times to insure that observations are eventually distributed over all hours of the day and week. Justification for the use of fixed interval sampling was given by Davis (1) who pointed out that provided the work contains no strongly periodic aspect, sampling (i.e. observations) at regularly spaced intervals will give better results than would sampling on a random time basis. Haines (3) Kinniburgh and McTaggart (4) and Wolff (6) also report satisfactory results from fixed interval sampling.

One attractive feature of the random work sampling technique is preserved when fixed time intervals are used, namely that interruptions in the schedule do not invalidate the results. If a particular round of observations runs over time, the following round, which cannot be started at the scheduled time, is omitted. Observations may be conducted for half a day or for one hour only, provided the work pattern is similar throughout the working day. In most nurseries the work pattern may be similar from day to day but there will be variations according to the hour of the day. Therefore if observations are made for one hour only, it is well to record the particular hour, and make additional observations on other

TOTAL CENTS PER MINUTE C	FREQUENCY (ROUNDS) F	F × C	F × C²
0	3	0	0
8	2	16	128
10	4	40	400
12	5	60	720
14	10	140	1960
16	10	160	2560
18	12	216	3888
20	4	80	1600
Σ	50	712	11256

FIG. 3. Frequency Distribution of Total Costs in Cents per Minute of the Potting Operation.

CATEGORY		TOTAL
POTTING	𝍸 𝍸 𝍸 𝍸 𝍸 ///	28
DELAYS:		
WAITING FOR POTS	//	2
WAITING FOR SOIL		
WAITING FOR PLANTS		
PERSONAL	/	/
AVOIDABLE DELAY	/	/
TALKING TO SUPERVISOR	////	4

FIG. 4. Evaluation of Delays in the Operations of Potting.

days at some other hour.

The results shown in Figure 1 are for one day's sampling. The total of 540 is not an exact multiple of the 42 employees since a few of the women finish work at 3:30 P.M. This is the normal time for these girls to finish work, and they are merely omitted from any round of observations starting at 3:30 or later. If, however, an employee is on paid vacation or special (paid) leave of absence an appropriate category should be included on the tally sheet, and a check mark made in it on each round that occurs during the employee's absence.

It is well to point out that such a large number of observations, as shown in Figure 1, would not normally be made in one day. A better estimate of the proportion of time devoted to a particular job would, in general, be obtained by distributing the observations over several days, arbitrarily choosing different days of the week and different weeks. Better still if sampling is done throughout the year not only will the estimates of time proportions be more reliable but information on seasonal variability will be made available for management.

ADDITIONAL USE OF THE METHOD

Upon examination of Table 1, it is clear that certain of the operations listed are responsible for a large amount of the total time. The operations with large values of percentage time are the ones that may give greater opportunity for cost reduction from improved methods. An obvious example is the "potting and flatting" category which has been shown to consume 15% of the total labor force.

A detailed work sampling study of the potting operation may be desirable at this stage. The general procedure is similar to the methods already described except that only the girls engaged in potting and flatting are observed. A sample work sheet is shown in Figure 4. Clearly the "delay" categories may be modified to suit the operation at a particular nursery, since the "potting" operation may include moving the plants to the greenhouse, removing seedling flats from the propagation house, etc.

CONCLUSIONS

The proper use of a simple fixed-interval work sampling technique, using a type of tally sheet shown in Figure 1, will give reliable proportions of the total labor force employed on each operation. These proportions are more reliable than might be obtained by a similar expenditure of time and effort on normal time study, and moreover the work sampling study can be done, with a little training, by a competent member of the office staff.

A slightly more elaborate tally sheet such as Figure 2 enables cost analysis to be performed in organizations with a heterogeneous wage structure. In the example given there was very little difference in the cost per unit time of the "potting and flatting" operation when computed from observations on either type of tally sheet, due to the homogeneity of wage rates in the nursery studied.

Operations which consume the larger fractions of total man-hours will repay closer study by the same methods to evaluate delay in the operation. If the employees engaged in such an operation have a variety of pay scales it may be desirable to construct a tally sheet similar to Figure 2, in order to evaluate costs of delays. Reduction of any delay to a minimum will clearly lead to an improvement. The actual operation itself may repay careful analysis which can lead to an improved method of performing the task.

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Integration of Operations Research into the Firm

by **ALBERT H. RUBENSTEIN**

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THREE phases are observable in the initiation and integration of a new staff function such as Operations Research into the firm.

First there is the introductory phase in which one or a few tentative overtures are made toward forming a group to carry on this new function or toward trying it on an experimental basis without commitment to a new department or group.

If the new function survives this phase—one in which sponsorship and the general auspices of the trial run are critical—a group may gradually be formed to carry it on as a full-time activity. This is the *second* or transitional phase.

A *third* phase—if it is ever reached by the new function—is its establishment as a continuing, routine company activity with no special consideration from top management that is not afforded to other important activities in the firm.

Many modern staff activities in the firm have passed through all three stages in the past few decades and are no longer considered new or unusual enough to occupy more than routine management attention. Industrial Engineering, cost accounting, and production control are examples of such staff activities that have reached maturity in most progressive companies and which have been successfully integrated into the firm.

Other relatively new activities are still going through stages one or two in most firms although some of them appear to be well established. These might include quality control, controllership, market research, research and development, and integrated data processing, for example.

We must recognize, of course, that a particular function does not reach maturity simultaneously in all firms at once. For example, quality control in many firms may have been in stage three for years, but may not have completed stage one in many other firms in the same industries.

In each of these three phases, management has certain design decisions to make affecting the new activity which can strongly influence its success in that phase and its survival into the next.

Some of these decisions are minor tactical ones. They will have some influence on the success of particular projects and their results, but they may not be critical with respect to the ultimate success of the function. Some of these will be mentioned in passing, since they do have a cumulative importance. But this article will concentrate on a set of strategic decisions whose effect on the success of the new function can be direct and decisive.

Three sets of strategic design decisions make up the inputs to the new activity. They establish the conditions under which it will operate and the resources at its command.

They will be discussed in the following order, in connection with the Operations Research activity:

1. The *objectives and tasks* assigned to and undertaken by the Operations Research activity.
2. The *operating conditions* under which the Operations Research function is performed.
3. The *resources* assigned to the Operations Research activity.

OBJECTIVES AND TASKS

Under objectives and tasks, one may discern a hierarchy of decisions related to the motivation for initiating an Operations Research activity, the over-all objectives set for it, and the criteria for selecting and emphasizing specific projects.

When entering the first phase—which essentially amounts to flirting with the ultimate possibility of having a permanent Operations Research activity in the company—the motivations of the sponsors and their supporters are critical.

Is the sponsorship of an Operations Research activity motivated by the feeling that current methods of problem analysis in the firm are inadequate? Or is it less a question of adequacy than it is of convenience? For example, are the skills and procedures commonly employed by operations researchers available in the firm but not sufficiently accessible?

These motivations as well as the advertised objectives of the new activity should at least be clear in the minds of the sponsors of the group so that they can be logically and systematically translated into a basis for other strategic decisions such as project selection, organizational responsibility, effectiveness measurement. and so on.

Some of the confusion which has resulted from introduction of Operations Research and other new activities into the firm can be traced to a lack of a clear concept of the objectives of this activity *in* the firm.

In some instances the new activity was, incorrectly, viewed as a fire-fighting or emergency measure which would begin to pay off the day after it was initiated into the company. Disappointment with a failure to achieve this immediate goal has led to the quick death of the activity and, perhaps, a blocking of another attempt for some time to come.

If Operations Research is introduced primarily as a weapon in an organizational power struggle, its sponsors must recognize that it can not only fail to fire but can also backfire. A number of recent cases in the integrated data processing field illustrate this. The new activity was introduced as a move in a power struggle and backfired seriously—in two cases resulting in the termination of its proponents.

In the more general case—the one where power is not the issue—the necessity for careful consideration of objectives is also crucial. What is it that you want Operations Research to accomplish that is not now being accomplished in the firm? If this question can be answered in fairly specific terms, then the next step is to attempt to translate this statement of objectives into more precise terms—to develop criteria of effectiveness for the proposed activity.

In phase one—the flirtation or trial period—the criterion can be fairly simple and binary. For example: after the expenditure of so much time and effort (to be designated as a fair trial), does it look as though this activity has sufficient promise to carry it further?

One of the reasons for ultimate failure or unrealized potential of many such new activities is the unwillingness of its sponsors to establish and *use* clear criteria of their usefulness. No one is willing, for example, to say that this activity is or is not a good bet for further investment. Instead, in many cases, the activity either dies by default —through lack of budgetary provision for its continuance or continues by default—through lack of a decisive cut-off order.

In the latter phases, when Operations Research is evolving into a permanent, routine operation, the need for criteria of effectiveness continues. It is difficult, of course, to measure the gains from Operations Research or from similar activities such as quality control or research and development. This sometimes results in precipitous action in times when money is scarce or when sales and profits drop. For example, a company which spends a large amount of its cost dollar on engineering recently suffered a reduction in sales. One of the first activities cut out was the Operations Research group, despite the fact that it had been conducting a study attempting to reduce engineering costs.

The lack of ability to measure results completely in dollars and cents does not mean that evaluating the Operations Research function is a hopeless task. A number of Operations Research groups have recently reported dollar savings figures from specific projects. But the effectiveness of such an activity may not lie only in the direct annual dollar savings. Certainly in the third stage —the period of maturity—there are many functions the progressive firm supports without asking for continual profit and loss figures. Research and development is one and quality control is another.

The point here is that if objectives are reasonable and clearly stated, it is possible to establish general criteria—some in dollars, some in other terms—that will provide control limits for the usefulness of the Operations Research activity. Such a strategy will provide the basis for changing objectives, if it appears that the criteria are unreasonable; or it may permit occasional re-design of the way that the Operations Research activity is organized and the conditions under which it operates.

If the objectives and effectiveness criteria for the Operations Research activity are properly stated, it should be possible to derive from them the general *project portfolio* for the activity and the specific projects to be undertaken.

If, for example, the objectives include only "cost savings in manufacturing" and the activity is to be evaluated on the basis of how much it saves each quarter or each year, then the project portfolio—the projects it works on at any given time—will be directed at short term cost savings in the factory.

If the objectives are broader and include general responsibility for "improvement of operations in the company"—then management must consider encouraging and supporting a much broader and longer-perspective program.

The important thing is that the people involved in Operations Research and others in the firm whose functions might be affected by Operations Research should be aware of the relative breadth and depth of mission assigned to the group. And there should be the opportunity to modify this mission and the project portfolio as the abilities of the Operations Research group change and its usefulness to the company is demonstrated.

One behavior of some Operations Research people in firms which are trying their wings in this field, is the absence of a clear strategy for gaining acceptance and achieving results in phases one or two. This, I believe, is one of the primary responsibilities of the sponsors of the new activity. Even in phase one, the person or people actually attempting to perform Operations Research may be new to the firm or at least new to the lofty corporate heights at which Operations Research is sometimes temporarily attached.

In these circumstances, the Operations Research technicians will probably not have a firm grasp of company-wide operations, corporate politics, and the personalities of the people in the firm who can boost it or knock it. It is here that sponsors who presumably have this knowledge can combine it with the analytical ability of the Operations Research people to evolve a project portfolio strategy that will assure survival into at least phase two.

Strangely, the analytical ability of the Operations Research man is seldom brought to bear on this problem, although it is no more complex than some of the others he tackles. In essence, it is a decision problem under risk, if his sponsor really knows the company, and under uncertainty if this knowledge is not very good.

The variables are those of a straightforward decision problem: there is a (usually) finite number or class of projects that might be undertaken, a probability distribution for the consequences associated with each alternative, and a way of evaluating these consequences either in units like dollars saved or prestige gained or some other such measure.

The analytic decision problem—given the set of alternatives, the probability of outcome, and the value of the outcomes—is simple. The difficult and critical part, of course, is getting to these "givens." It is here that the sponsor, the organizationally sophisticated management man, is vitally necessary. And here is where he frequently lets his Operations Research boys down. His attitude may be, "They're bright boys; let them sink or swim. I got them into the company, didn't I; what else do they want?"

What I am advocating here is a much different attitude—one in which the sponsor enters actively into this first model-building problem taken up by the Operations Research people.

The actual decision-making model for this strategic decision-making problem need not be very complex. A very simple graphical one—with analytic handles on it may be quite adequate. Consider, for example, all possible projects placed in a matrix or table constructed as in Figure 1.

Probable gains from successful resolution of the problem				
		HIGH	MODERATE	LOW
Probable cost of performing this project (dollar cost, probability of prestige penalty, etc.)	LOW			
	MODERATE			
	HIGH			

FIG. 1

This is a very rough and ready approach, but can rapidly be refined analytically. The point here is the need for a strategy of project selection and of the project portfolio and a means for establishing time priority for projects.

Certainly, it may appear attractive for the Operations Research people in phase one to make a play for high gain, low cost projects, and to avoid low gain, high cost projects. And this might be the proper thing to do strategically. But it might also be a bad thing to do strategically.

Suppose, for example, that there are a lot of high-gain, low cost projects lying around the company in various areas of the factory, the offices, the research laboratory, etc. These might conceivably be a sort of stockpile that various other staff groups—e.g. Industrial Engineering, office systems, the research lab—have not yet gotten to, or perhaps, are even hoarding against a rainy day. The momentary triumph of dusting them off quickly may doom the Operations Research activity from the start in the view of these other functional groups.

Selection of only the easy projects with the quick, high pay-off may serve as an initial impetus for the Operations Research activity, but continuance of this strategy into phase two may be suicidal. First of all, with the other staff groups better established and with more resources—both economic and organizational—this mine of problems will probably be worked out very soon.

Secondly, if all that the Operations Research activity serves to do is to point out that the other activities have been missing such problems, the result may be that the other activities are chastised or strengthened and the Operations Research activity receives a great big vote of thanks and a termination notice.

If there is a distinct legitimate function for the skills and approach of Operations Research in the firm, then it has to be demonstrated. The project portfolio must reflect not just a lucky strike of quick-fix problems, but an area of problem resolution and problem recognition that other staff groups or other bright individuals in the firm could not or would not deal with.

Some of these very important "exclusive" or "untouchable" problems—(untouched by other groups, that is), may be in the moderate and high cost area and they may lead to only moderate or, hopefully, high gains. The precise calculation of marginal return from certain classes of problems is a matter for the analytical refinement of the decision-making model mentioned above.

It is these moderate and high cost projects, often involving long time periods and high risk of failure that should distinguish the Operations Research group in phase two, and certainly in phase three from the many other routine problem-solving staff groups.

In the early phases, consideration should also be given, subject to the marginal considerations of the model, to knocking off in addition a number of the low-cost, low-gain projects as a prestige building or warming up exercise. Positive gains, no matter how small, may be important in the early phases when people may be counting problems solved as well as dollars saved. This class of problems, serving many warming up and orientation functions for the Operations Research group itself, may avoid the danger of robbing someone else's stockpile of problems; the other groups may not be interested or even aware of some of them.

The strategy I am proposing is a balanced portfolio of projects which is developed from the important strategic objectives in each phase. In the early stages, the project portfolio should, perhaps, be directed at building prestige and good will, achieving acceptance of the activity in the firm. Later, it may be necessary to include some projects with long term implications for the company and for the development of the Operations Research personnel.

Whatever the background and skills of the Operations Research people, attention must be paid to their professional and practical abilities. Problems of a routine nature with no theoretical implications can soon discourage Operations Research people who are interested in advancing their professional stature and tackling more advanced problems continually. Giving all members of the activity opportunity to learn about the company operations may also be an important, continuing strategic objective in project selection.

It may also be necessary for certain members of the Operations Research activity to specialize in a given class of problems over a long period in order to reach a high level of understanding of the phenomena involved so that the desires for breadth and depth of knowledge of company activities have to be reconciled in the project portfolio continually, not just in phase one.

One special class of problems has caused difficulty in a number of firms where Operations Research was still in phase one. In one or two of them I expect that they will never reach phase two and certainly not phase three. These are the class of organizational problems that involve issues like: division of responsibilities between executives, long range planning of the company's sales policies, effectiveness studies of particular functions, and the like.

Some of these problems fall into the class that might be called "politically difficult." They just may not be the kind of problems that a brand new group should undertake in its first few months or years in the company. I have seen several cases where this kind of study was not acceptable, coming from this kind of group because of its age, the age of its members, and its ambiguous position in the company—that is, sponsorship.

A second, and even more compelling reason to avoid this class of problem in the early stages, perhaps forever, is this: With the present state of knowledge about organizational behavior, or organizational theory, the Operations Research man may be in no better position to resolve organizational problems than anyone else in the firm and he may be in a lot worse position due to his lack of knowledge of the personalities involved and the organization's history. His mathematical models and abstractions from reality may get him into real trouble in problems where measurement is not feasible and abstraction is self-defeating.

The penalty for failure in a problem of organization—relations between groups, definitions of responsibilities, setting company objectives and policies, etc.—may be the guillotine, not just a black mark in the book.

As the Operations Research activity matures, of course, and as organizational problems are recognized which have analytical implications, then, the Operations Research activity may make an important contribution as part of a task force or in cooperation with the increasingly evident organizational research or planning groups.

OPERATING CONDITIONS

Under this heading, three aspects are discussed:

1. Organizational location of the Operations Research activity.
2. Relation to other groups in the company.
3. Organization of work within the Operations Research activity.

ORGANIZATIONAL LOCATION

The initial and ultimate organizational location of the Operations Research activity may be critical.

Certainly, in the early stages, a new activity of this type needs high level sponsorship and can use all of the derived status it can get. It needs this prestige and status in all phases of its work—getting information that people may be reluctant to supply, gaining cooperation in experiments, achieving implementation of its results, uncovering new problem areas, and so forth.

Two questions arise in this connection; one is whether the authority and power to elicit desired action should accompany this prestige and general status. That is, if the Operations Research activity is attached to the executive vice president on the organization chart, should it be implied that people in this group speak with his voice.

The difference here is between the prestige afforded by being attached at a high level, indicating that company management thinks this is an important activity, and the effective power imputed to the group by its organizational location or sponsorship.

The second question is: how long should this new activity be maintained in a usually ambiguous location of this type.

In the absence of clear policy on this issue of organizational location, it is easy for a temporary location, primarily for the purpose of providing an initial prestige impetus, or a bird's eye view of the company, to become a permanent attachment and an extension of the activities of the sponsoring executive.

In some cases, this may not be a bad idea. Perhaps the Operations Research activity should, logically, become a part of the controller's office or the staff of the vice president of something. This may not be a bad idea if the logic can be established independently of the historical accident that placed it there temporarily.

The easiest course of action is to say: "Well, the group has been working nicely in Bob's or Sam's department even though the original decision was somewhat accidental. Let's leave it there a while longer."

This issue of organizational location can be a two-edged sword. In addition to the prestige, etc. that a particular location can provide, there is also the possibility of a functional connotation being imputed to it. For example, if it is located in manufacturing, it may be natural to assume that it will confine itself, or at least concentrate on, manufacturing problems.

All of the historical company relationships between departments provide a set of expectations about how

members of these departments will behave. Suppose the controller's office has historically been concerned with only budgetary and cost matters, in a technical accounting sense. If the new Operations Research activity is located there and begins to look into sales policies, personnel allocation problems without an immediately obvious accounting connection and other "apparently peripheral" matters, people's expectations will be violated and trouble will ensue.

In addition, the new activity will probably inherit all of the personal antagonisms and rivalries that exist between its sponsor and others in the company. This is the negative aspect of the derived prestige; it may derive some low status as well.

The question of how high level the location should be is relevant here. If Operations Research is to be introduced as a sort of cooperative problem solving venture for the various activities of the firm, then one should avoid giving the impression that this is a top management tool for checking upon or showing up the deficiencies of existing activities.

Location at too high a level, therefore, can ultimately doom Operations Research as well as give it initial impetus.

If the purpose of the initial location is merely impetus or t[illegible]ird's eye view, then it should be relocated as soon as possible after these objectives have been accomplished. That is, as soon as the criteria of effectiveness for phase one indicate success in this phase, move it into phase two. And furthermore, if the disadvantages of high level initial location are to be reduced, it should be known in the company that phase one is merely temporary.

In addition to organization level, the other important location parameter is functional area. This is discussed next.

RELATION TO OTHER GROUPS IN THE COMPANY

Relations with other activities in the company will always be an issue for an activity like Operations Research. By its nature, the Operations Research activity is concerned with areas of the firm's operations in which groups are already established—operating groups such as production, marketing, and finance—and the staff groups supporting them.

Questions of overlap, division of responsibility, conflict of interest and so on must eventually be resolved to the point at which they do not interfere significantly with the effectiveness of the Operations Research activity or that of the other groups. I do not believe that these questions can be resolved permanently or completely any more than similar issues involving research and development and other functions have been.

Where there is intimate contact, particularly in a flow-of-work relationship—one group feeding information to another—there is always the potential for conflict. The trick is to keep it below the critical level.

One way of helping this situation is to pay a good deal of attention to specialization and division of labor. This is important in both the initial phases where objectives are being evolved and in the continuing situation. In the latter case, the list of projects is examined continually to see who is to do a particular job and how it is to be shared by different groups.

The question of a legitimate role for Operations Research arises again here. Does Operations Research have a role defined primarily in terms of functional areas of the company? This was examined by surveying the articles in the *Journal of Operations Research* over a two-year period which had involved industrial operations. Here are the subjects they covered:

Value of an Engineering Design.
Economic-Lot-Size in Manufacture.
Manufacturing Specifications.
Production Scheduling.
Research in Marketing.
Sales Response to Advertising.
Distribution of Seasonal Inventory.
Allocation of Sales Effort.
Company Planning.
Spare Parts Programs.
Inventory Markdown.
Warehousing Problems.
Reorder Points.
Machine Repair.
Sales Operations.
Staff Organization.
Selection of Capital Equipment.
Management Planning and Control.

Additional data on this point are presented in a recent survey of Operations Research in the United States (3).

There are few, if any, of these problem areas in which the modern manufacturing corporation does not already have a staff group primarily or secondarily concerned with the subject matter.

So it seems that subject matter, or functional area, is not an adequate basis for differentiation of the Operations Research activity from that of other staff activities.

This is in sharp contrast with the function of, say, quality control or physical research where the area of activity is clearly defined relative to other functional areas and the groups in those areas are undisputed (or relatively undisputed) entrepreneurs over them.

I believe that there *is* a clear and legitimate rationale for the Operations Research activity in the firm. It is based, not on *functional* specialization, but on the concept of depth or perspective in many areas of the firm's operations.

Consider the typical project portfolio, the allocation of effort, of the existing staff groups. At the risk of too broad a generalization, I will describe them this way: they are generally involved with immediate problems affecting current operations of the functions to which they are attached.

Thus, a typical production control staff group will

be concerned with current production schedules, perhaps with schedules for products coming into production soon, and possibly for products that may be coming at a later date. They, or another group, may also spend some time on refining the production scheduling and control techniques they are currently using and examining newer techniques that have been suggested by suppliers or in the literature.

Very rarely will you find a traditional production control group considering issues like the following:

What is the concept of control of quantity of output?

What are the fundamental relations between quantity, quality and method of manufacture?

What are the over-all capabilities of the firm with respect to delivery lead time and what does it cost, over-all, to produce much sooner or much later than promised?

What are the inherent capacity characteristics of a machine or a unit operation? How do these relate to economic lot size, minimum inventory levels, purchase terms, repair and maintenance policy and so on?

The rationale appears to me to include the necessity for a capable group to raise this kind of question and to undertake studies which other groups are not interested in or capable of undertaking.

The Operations Research activity is widely needed as a *research* activity and not an *operational* staff group. It can raise fundamental questions about operations, developing new methods of data collection and analysis and evolving new control and decision-making tools for use by operating people and their staff groups. They can be concerned with problems that cut across traditional functional lines, problems that may at present be in a functional no-man's land between staff groups or that may be inundated by too much uncoordinated effort from too many different points of view.

The lack of interest or ability of existing groups to undertake such problems may stem from a number of causes. For example, the training of the functional specialists in these groups may have excluded or been incompatible with the kind of analytical approach in which the Operations Research group is trained. In much traditional Industrial Engineering training, for example, the starting point is the existing operation or phenomenon. The questions raised are how can it be improved or changed, etc. In general, the question of the basic nature of an operation is not a part of the formal training. Further, the viewpoint is generally focused on isolated operations or parts of operations and the analysis is directed at optimizing that fragment of the company's activity.

The traditional training and behavior of many cost accounting groups do not generally involve questions of the source and the basic nature of cost information. In a very proper sense, organizationally proper, that is, they avoid raising questions which impinge on the prerogatives of other functional groups—those which supply their cost data or use it to control costs.

Research and development people may be uninterested in examining their own behavior from an efficiency or an effectiveness point of view. They may also be more interested in problem-solving than in how their problem solutions may affect the company's over-all business in years to come.

These comments are not intended as a flat statement that such staff groups do not ever undertake such studies and raise such questions. Quite to the contrary, some of the best of what we are currently calling industrial operations research is in fact being performed in a number of companies by Industrial Engineering, cost accounting and research and development groups.

The point is that where there is a basic lack of such activity in the firm, where these other staff groups do not undertake to raise such questions and conduct such studies, there is a need for the contribution that Operations Research can make.

I would like to draw a distinction here between the need for this kind of activity, where it is lacking, and the need for a specific group of people with separate organizational identity such as the "Operations Research Department" or "Operations Research Group." If the need for this broader-gage, longer-range analytical thinking can be met by existing groups in the firm, then this may be a better organizational policy.

My observations, however, suggest that in many companies the separate group would be a better solution. This viewpoint is related to the earlier discussion about the project portfolio. It is very unlikely that all of the research on methods and concepts of the firm's operations could compete successfully with the day-to-day routine and trouble shooting requirements in most of these staff groups.

Many staff groups, such as quality control, have pet projects of a long range nature that they would like to work on if given the facilities, the time, and, in some cases, specialized talents. But the pace of operations and the current requirements mitigate against such longer-range and broader-scope projects.

They fare well only when they are the major responsibility of a special group like Operations Research.

If a separate Operations Research activity is to be established in the firm, then the foregoing comments strongly imply the necessity for an integration of the Operations Research activity with these other staff groups.

In this connection, I visualize a flow of work between Operations Research and these other staff groups similar to that indicated in Figure 2.

I visualize two major paths of information flow:

1. Problems arising in operations which the operating staff groups are not equipped to handle are referred to the Operations Research activity for longer range or broader or deeper examination. Solutions are transmitted back to the staff groups which in turn refine and translate them into operating tools.

2. New ideas, new methods, general concepts, which originate with the Operations Research group or which stem from problem solving in other functional areas, are transmitted in general form to the staff groups and again translated into operating rules and tools.

In other words, I visualize this process, at maturity, in terms analogous to the activity of the various research and development groups which are concerned primarily with the physical aspects of operations, contrasted with Operations Research's primary interest in the economic and other non-physical aspects.

This process requires very strong links between Operations Research and other staff groups and a condition of mutual support rather than competition. Each is both a supplier of information to and a user of information coming from the other group.

There will, due to the differences in the nature of the people involved and the necessity for contact, be a high potential for conflict between these groups and this is where an alert management can make sure that the level of conflict does not interfere seriously with the flow of work.

The Operations Research group should avoid posing threats to the intellectual or job security of people in these other staff groups. To some etxent this depends on the personal qualities of the people involved. But a lot can be done through organizational devices such as project task forces, exchange of personnel, and doing everything possible to indicate that this is a cooperative venture rather than a competitive one.

ORGANIZATION OF WORK

In this connection, the internal organization of work of the Operations Research activity is important. The question is whether work should be organized on a functional basis—all specialists of one kind in a group, lending out their services as needed for particular problems—or on a project basis, in which all the skills necessary to solve a particular problem are grouped together for the duration of the project.

Combinations of these two "pure" forms are possible and more usual than the pure forms themselves. The actual pattern of operation in these terms, functional or project, will have a strong influence on the integration achieved with other staff groups. The pattern of internal organization will also affect the ability of the Operations Research activity to maintain a reasonable project portfolio including short and long term, broad and narrow problems.

In the recent literature of research management this particular issue is becoming a popular one and there are a number of good articles dealing with it in the research, development, and engineering functions that are also relevant for designing the Operations Research group (2).

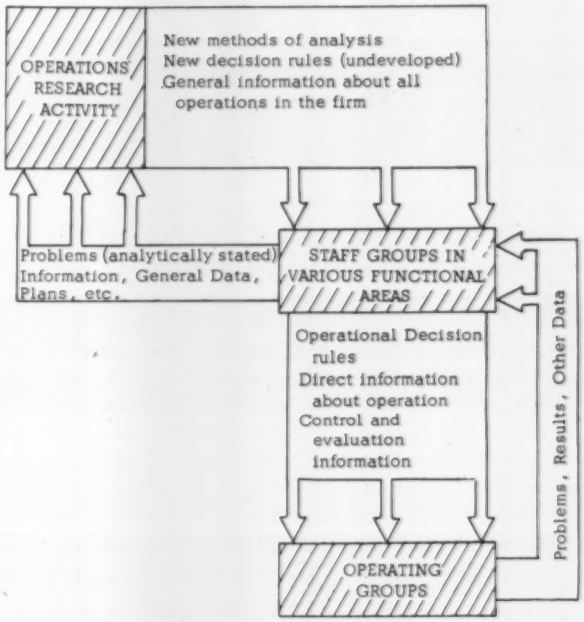
OPERATIONS RESEARCH ACTIVITY
New methods of analysis
New decision rules (undeveloped)
General information about all operations in the firm
Problems (analytically stated)
Information, General Data, Plans, etc.
STAFF GROUPS IN VARIOUS FUNCTIONAL AREAS
Operational Decision rules
Direct information about operation
Control and evaluation information
OPERATING GROUPS
Problems, Results, Other Data

Fig. 2

RESOURCES

In this final section I would also like to refer to the voluminous and rapidly growing literature of research management. Under the heading of Resources for the Operations Research activity, are subjects such as the size of the group—on the assumption that an independent group is indicated in phase three; the mixture of skills necessary, the facilities and equipment required, budgetary procedures, accounting for costs, etc. There are also several pertinent bibliographies in the research management field (1) (4) (5).

Finally, here are a few comments about several of these resources for the Operations Research activity.

First, on the size and make-up of the group, there is a notion in research management about what is called a "minimum effective" research group. This is a group with the minimum necessary skills and abilities to do useful research. This concept is usually discussed in connection with research creativity. The minimum requirement is for at least one highly imaginative and creative person as the nucleus for a research group in order to provide stimulation and leads for the group. Without such a person, the research group may be ordinary—capable of routine problem solving but not of imaginative new leaps into the unknown. The research department should then be made up of a number of these minimum effective groups, subject to the limitation of stretching the nucleus too far; that is, of exceeding a "maximum effective" group size.

An additional comment on make-up relates to the kind of specific skills. Because of the nature of Operations Research work, I believe that an Operations Research

group should have, in addition to the analytical abilities usually supplied to it, an element of experience and sophistication about operations themselves and the business the company is in. Some Operations Research activities have been composed principally of industrially naive groups of physical scientists on what I believe to be a false assumption. This assumption appears to be that since many naive groups were so successful in wartime military Operations Research, that it is the very quality of naiveté about the specific operations they are studying that was responsible for their success. I reject this assumption for the industrial Operations Research group and advocate a high level of sophistication about company operations. This sophistication is not to be confused with mere years of experience which may simply be a repetition of a very low level of sophistication.

In summary, I have suggested that there are three phases in the integration of Operations Research into the firm. Three sets of strategic design decisions should be made in this connection. The first involves objectives and tasks of the Operations Research activity:

1. Here the motivations and sponsorship for the Operations Research activity are important.
2. If objectives are properly stated, the project portfolio can be derived.
3. A decision making model was suggested for building the project portfolio.
4. Some specific classes of problem should be avoided in the early stages.

The second set of decisions involves operating conditions.

1. Organizational location was discussed, as well as the potential dangers of improper location.
2. Relations with other activities emphasized the flow of work between Operations Research and other staff groups, and proposed that Operations Research be a supporting group for these other activities, in a real research role.
3. The internal organization of work will affect this relationship.

The third set of decisions relates to resources assigned to the Operations Research activity in phase three, on the assumption that it becomes a permanent group.

1. The decision problems here are analogous to those in research and development which has a new and specialized literature that may be of great help.
2. The notion of the research nucleus was described, and I would like to close by saying that the quality of the Operations Research work done in the firm cannot be divorced from the quality of the people assigned to carry it out.

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Reader Comments

SIMULATION AS A PRODUCTION AID, by John L. Colley, Jr., *Journal of Industrial Engineering,* July-August, 1959.

This is a brief reply to the comments on John L. Colley's paper which were published in your Reader Comments section in the January-February, 1960, *Journal.*

I think my approach, while certainly not original, is unfamiliar to most Industrial Engineers and thus would be of general interest to your readers. It should also clear the questions arising in the letters of Professors Burgess, Colley and Page.

These letters have reopened the question of the distribution of sums and differences of random variables—in particular *normally* distributed random variables. The following proofs attempt to substantiate Professor Burgess' comment, "... I think I am right in stating that the sum or difference of normal distributions is of itself a normal distribution." These proofs, it must be pointed out, are not original with me and I do not know their origin. They are given in Cramer (1) as elsewhere.

Proof that the sum of n normally distributed random variables is normally distributed.

First we use some results from generating functions so as to make the generalizations more simple.

1. The generating function of a random variable is defined as

$$\Psi_x(t) = \int e^{tx} f(x)dx \qquad \text{Eq. 1.}$$

2. The generating function for the distributions of the sum of independent random variables is given by the product of the separate generating functions:

$$\Psi_{x_1+x_2+\cdots+x_n}(t) = \Psi_{x_1}(t)\Psi_{x_2}(t)\cdots\Psi_{x_n}(t) \qquad \text{Eq. 2.}$$

3. There is a one to one correspondence between a frequency function and its generating function.

Now: The frequency function for a normally distributed variable is given by:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\bar{x})^2/2\sigma^2}$$

The generating function is given by:

$$\Psi_x(t) = \int_{-\infty}^{\infty} e^{tx}\left\{\frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\bar{x})^2/2\sigma^2}\right\} dx$$

Integrating,

$$\Psi_x(t) = e^{\bar{x}t+(\sigma^2t^2)/2} \qquad \text{Eq. 3.}$$

Inspection shows that the generating function *for the normal* retains the mean and variance of the distribution explicitly.

Now: If we add n variables (x_i) from a normal distribution with means $\bar{x}_i$ and variances σ_i^2, then each generating function is as above and in Eq. 2. the ith generating function

$$\Psi_{x_i}(t) = e^{\bar{x}_it+(\sigma_i^2t^2)/2}$$

Hence

$$\Psi_{x_1+x_2+\cdots+x_n}(t) = e^{\bar{x}_1t+(\sigma_1^2t^2)/2}\cdot e^{\bar{x}_2t+(\sigma_2^2t^2)/2}\cdots e^{\bar{x}_nt+(\sigma_n^2t^2)/2}$$

$$\Psi_{\Sigma x_i}(t) = e^{(\Sigma\bar{x}_i)t+(\Sigma\sigma_i^2)t^2/2} \qquad \text{Eq. 4.}$$

It is obvious that this is of the same form as the generating function for each x_i; hence this is the generating function for a distribution with mean $\sum\bar{x}_i$ and variance $\sum\sigma_i^2$.

By 3., this generating function uniquely determines a frequency function. Since the generating function for any normal curve is of the form $e^{\bar{x}t+\sigma^2t^2/2}$ and since the $\Psi_\Sigma(t)$ is of this form, then the distribution of the sum must be normal.

Now it can be shown that

$$\Psi_{ax}(t) = \Psi_x(at)$$

Thus

$$\Psi_{-x}(t) = \Psi_x(-t)$$

Hence, if x_1 and x_2 are each normally distributed with mean $\bar{x}_1$ and $\bar{x}_2$ variances σ_1^2 and σ_2^2 respectively then

$$\Psi_{x_1-x_2}(t) = \Psi_{x_1}(t)\Psi_{-x_2}(t) = \Psi_{x_1}(t)\Psi_{x_2}(-t)$$
$$= e^{(\bar{x}_1-\bar{x}_2)t+(\sigma_1^2+\sigma_2^2)t^2/2} \qquad \text{Eq. 5.}$$

Again, a normal curve generating function but now with mean $\bar{x}_1-\bar{x}_2$ and variance $\sigma_1^2+\sigma_2^2$.

Thus we conclude by substantiating Mr. Burgess' comments that the distribution of the sum or difference of 2 independent random variables, each of which is normally distributed with mean $\bar{x}_1$ and $\bar{x}_2$ and variance σ_1^2 and σ_2^2 respectively, is a normal distribution with mean $\bar{x}_1+\bar{x}_2$ or $\bar{x}_1-\bar{x}_2$ and in either case the variance is $\sigma_1^2+\sigma_2^2$.

This same approach can be used to show that the distribution of the sum of 2 independent gamma distributed random variables is gamma distributed.

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——*Ralph L. Disney, Associate Professor, Industrial Engineering, The University of Buffalo.*

CYCLIC SERVICING, by Thomas F. O'Connor, *Journal of Industrial Engineering,* July-August, 1959.

My article on Cyclic Servicing appeared in the *Journal* of July-August 1959. Lately, in making use of the formulae therein, I found that I had not originally proceeded to the limit in simplification, and in addition that there was one more practical point to be covered. This is that for many reasons, such as auxiliary work and the like, the principal operator does not always have his machines to himself all the time. There is an outside efficiency which I have called E_4 to be considered.

The enclosed notes are intended to take care of the above mentioned deficiencies in the original, and you may wish to consider publishing them in the Journal for the benefit of any people who may be interested.

In an earlier article on cyclic servicing of producing semi-automatic machines by one operator, it was shown that the average machine efficiency, E, was given by

$$E = 1 - \frac{s}{2\cdot n} \qquad \text{Eq. 1.}$$

where s is the average number of stopped machines encountered in one patrol, and n is the total number of machines in the operator's assignment.

Other relationships established were as follows.

$$y = \frac{120\cdot s}{q(2\cdot n - s)} \qquad \text{Eq. 2.}$$

where y is the average time in minutes for one patrol, and q is the average number of stops occurring per mrh (that is, per machine hour at 100%).

Also

$$y = \frac{2 \cdot n \cdot w + s \cdot t}{k} \qquad \text{Eq. 3.}$$

where w is the average time in minutes (or decimal minute) required to walk the distance from center to center of adjacent machines, t is the average duration (minutes or decimal minute) of a stop while the operator is working on the machine. Waiting time or rest time are both excluded from t. k is the fraction of each hour the operator is expected to be available for work. If his allowances are 20% (that is .20 as a decimal), then k is .80.

Eq. 3. allows for the operator walking back to his starting point along the full assignment of machines without doing any work. It appears this is not the usual situation, but that usually the machines are so arranged that the end of a patrol finds the operator back at his starting point. The expression for y then becomes as in Eq. 4.

$$y = \frac{n \cdot w + s \cdot t}{k} \qquad \text{Eq. 4.}$$

An expression for s was then derived, so that for a given assignment, n, and given time study particulars, s could be calculated, and thus the efficiency obtained. The correction which would make the expression applicable to the "closed circuit" situation, as in Eq. 4., was then indicated.

The purpose of the present notes is to obtain a method of establishing the assignment which will give a prerequired value of the efficiency. It is found that this approach is actually simpler than the other, and meets the need for a method of finding quickly what number of machines would be a reasonable assignment if all the machines were busy on the same sort of work. Incidentally the notes furnish an opportunity to take account of a complication left out of account in the original article. This complication refers to delays on the machines caused by auxiliaries or other factors not in the control of the operator.

As a preliminary it may be noted that operator work done while the machine is running has to be evaluated apart from work which is done with the machine stopped. But this does not mean that the two sorts of work have to be kept apart thereafter as in treating random servicing. On the contrary, they are added together as follows:

1. Find the total of all the work the operator does on or about his machines per mrh.
2. Find the total number of stops per mrh (this is q).
3. Divide the total time by q in order to get t, the average worktime per stop. There will be an example later.

Obtaining the New Formulae

The operator on his patrol passes a number of machines which are running before he comes to one which is stopped. This number will vary. Let the average number of machines per stopped machine be g. The constant g can have any positive value. Then $n_1 = g \cdot s$.

Production time is lost for reasons associated with the operator, and this time has been accounted for. But time is often lost also for reasons beyond the control of the operator. For instance a spinner, nominally in charge of n_2 spindles, effectively has a lesser average number because of interruptions by the doffer and other auxiliaries. If E_d is the over-all combined efficiency of these auxiliaries, and if the "lesser average number" is n_1, then

$$n_1 = n_2 \cdot E_d$$

In calculating the spinner's efficiency, E_s, the number n_1 is used; but in the course of his patrol the spinner has to walk past all n_2 spindles.

Taking these factors into account, Eq. 1., Eq. 2., and Eq. 4. become the following:

$$E_s = 1 - \frac{1}{2 \cdot g} \qquad \text{Eq. 5.}$$

$$y = \frac{120}{q \cdot (2 \cdot g - 1)} \qquad \text{Eq. 6.}$$

$$y = \frac{g \cdot s \cdot w + s \cdot t \cdot E_d}{k \cdot E_d} \qquad \text{Eq. 7.}$$

Then from Eq. 7., $$s = \frac{k \cdot y \cdot E_d}{g \cdot w + t \cdot E_d} \qquad \text{Eq. 8.}$$

Finally, $$n_2 = \frac{g \cdot s}{E_d} \qquad \text{Eq. 9.}$$

Example

Omitting irrelevant detail, the following shows the aforementioned in action in the case of spinning. Since every spindle can run or stop quite independently of any other, each spindle is a "machine," and an mrh is a spindle running hour (at 100%). n_1 and n_2 therefore refer to the number of spindles.

First, the time study data are shown. E_d has been found to be .85. Work factor, k, for the spinner is set at .80. Creeling and breaks take 2.28 hundredths of a minute per mrh with the spindle stopped. Cleaning (spindle running) takes .75 per mrh on average. Total work time 3.03 hundredths or .0303 minute per mrh. The number of stops per mrh, that is q, is .1087. Then the average worktime per stop, t, is .280 minute.

Summary. $k = .80$; $E_d = .85$; $k.E_d = .68$; $q = .1087$; $t = .280$. $t.E_d = .238$. $w = .0015$ minute per spindle.

The results have been worked out for four values of g as shown in Table 1.

TABLE 1

Line		Calculations		
1. g	5	10	25	50
2. $2 \cdot g$	10	20	50	100
3. $1/2 \cdot g$	.10	.05	.02	.01
4. $E_s = 1.0 - (3)$	.90	.95	.98	.99
5. $(2 \cdot g - 1)$	9	19	49	99
6. $q \cdot (2 \cdot g - 1)$	.978	2.06	5.32	10.75
7. $y = 120 \div (6)$ (mins)	123	58.5	22.5	11.2
8. $y \cdot k \cdot E_d$	83.7	39.8	15.3	7.61
9. $g \cdot w$	.0075	.015	.0375	.075
10. $g \cdot w + t \cdot E_d$	.2455	.253	.2755	.313
11. $s = (8) \div (10)$	340	157	55.5	24.2
12. $n_1 = g \cdot s$	1700	1570	1388	1210
13. $n_2 = n_1 \div E_d$	2000	1850	1630	1420

The values of the cycle time, y above are in minutes and include the operator's relaxation time.

The old method used assumed values of n to calculate the corresponding values of cycle time, efficiency and stops per cycle. This new method, starting with what is in effect an assumed value of the efficiency, E_s, seems much simpler and quicker.—*Thomas F. O'Connor, Management Consultant, Oakland, California; associated with the Institute of Textile Technology, Charlottesville, Virginia.*

THE PRODUCTION OF VALUES ADDED BY MARKETING, by Al N. Seares, *Journal of Industrial Engineering,* July-August, 1959.

My partner, with a glint in his eye, just dropped a copy of this past July-August issue into my hands, accompanied by the mischievous suggestion that I read the Seares' article. *Deja vu!* This is one aspect of a program that I have been peddling, with varying acceptance, these past several years.

It is clear that if we apportion standard income per unit according to the economic contribution of the various productive, distribution activities, that we obtain a statement suitable for many forms of control analysis. Assuming that each major apportionment of value added to materials represents form, time, place, service . . . etc., utility, an inference of the amount of each type of utility, in its dollar form, provides the desired method of apportionment of that value added to contributing activities.

For a simple illustration, take a garment manufacturer, with a substantial number of active stock numbers. Let us assume that selling price is computed as 150% of prime cost. Now, we observe that the labor/materials ratio per stock number varies substantially. If we construe the value added by production to equal 175% of direct standard labor cost, and if we subtract this, for each stock number, from the difference between net selling price and materials, and, if we, then, divide the difference obtained by the dollar figure for production contribution, we have a clear measure of economic preference. By performing a "risk-opportunity loss" analysis of sales value added per unit of productive dollar capacity, profit-optimized sales mix, product-mix, etc., programs are obtained.

The findings developed by studies along these lines can be of substantial importance not only to operating programs, but to policy decisions as well.

The approach implies block-diagram systems studies of operations flow throughout the firm, supplemented by a study of the statistical characteristics—and why—of that flow. The results of such a systematic study include not only statistical, logical models of the firm and its marketing problems, but provide an implicit means for dealing rationally with organizational problems, a systems approach which can be extremely helpful in eliminating the departmental redundancies in supervision and control activities.

One important by-product of these approaches is the elimination of highly-questionable pro rata burden distributions. Such allocations frequently produce product "loss" statements where the eliminating of the product would clearly reduce net income! (On such a basis, one client was prepared to reject an order at $8.25 per unit where we were able to show that a profit increase of about $1.00 per unit would actually result.)

General management control is effected in the following way. The end result of each department's activity is treated as an intermediate product. The operating profit derived from each department's operations is then charged with the undistributed expense to obtain net income. A restatement of the chart of accounts in a corresponding manner provides a meaningful procedure for variance analysis: forecast; actual at standard performance; actual performance.

More work in this direction seems essential if we are to get away from the "clerical cost reduction" approach to computers and get down to dealing with the really substantial income improvement areas of production, marketing, etc.—*Lyndon H. La Rouche, Jr., 333 Central Park West, New York 25, New York.*

REAL-TIME MANAGEMENT CONTROL IN A LARGE SCALE MAN-MACHINE SYSTEM, by D. G. Malcolm, *Journal of Industrial Engineering,* March-April, 1960.

Allow me to underline, by comment, an important observation presented by Donald G. Malcolm in his "Real-Time Management Control in a Large Scale Man-Machine System (2)."

"A management control system will be defined as a set of policies, procedures, information processing, which is designed to give direction to activities by clearly establishing goals, by measuring progress toward those goals and by indicating or initiating corrective action."

This view is considerably more encompassing than previous statements on the subject of controls, most of which dealt with the methods or characteristics of management control rather than the concept. Compare, for example, the "Requirements of an Effective Control System" which were perceptively analyzed by Koontz and O'Donnell (1). These authorities thoroughly describe the Principles of Control, but only suggest the *integrated* nature of a control *system.*

In the same paragraph, Mr. Malcolm may have evaluated for us the direction in which the future lies. He said: "It is significant to note that . . . the concept of integrated total system control still remains virtually unexploited."

These few lines put forth an extremely valuable concept.

REFERENCES

(1) Koontz, Harold and O'Donnell, Cyril, *The Principles of Management,* McGraw-Hill, New York, 1960, p. 588.

(2) Malcolm, Donald G., "Real-Time Management Control in a Large Scale Man-Machine System," *Journal of Industrial Engineering,* March-April, 1960, p. 103; previously published for presentation at the Management Control Systems Symposium of July, 1959, as *Systems Development Corporation Study SP-90.*

——*D. P. Kirchner, Lieutenant, USN Postgraduate School, Monterey, California.*

AUTHOR'S COMMENTS

Mr. Kirchner has amplified what was intended to be a very serious point in my article; namely, that better management information and control systems must be "designed." To do an adequate job of design, the engineer must know the purpose and objectives of management and make efficient use of the basic information developed for the various levels of management. This is particularly important with the increasing application of Electronic Data Processing.

Present practices which have not taken this over-all integrated systems approach have generally resulted in some of the following symptoms of poor system design:

Conflicting measures concerning the same operations.

Measures of performance developed by different functions of the company—e.g., manufacturing vs. finance—often give nonreconcilable results. When this occurs a conflict situation is set up that leads to what may be termed competitive or overlapping controls.

Duplication in the generation of fundamental source data.

Often old systems are not eliminated when a new one is instituted and multiple uses of the same data are not considered in system design.

No attempt at system evaluation.

Are the benefits produced by the new system worth the cost of providing same? This is a question requiring much more attention than is currently being given it.

Restrictive vs. Enabling Control Concepts.

The use of budgeting methods often forces spending money to keep from losing an allocation, rather than enabling higher performance toward over-all objectives.

Loss of "Integrity" of information through misapplication of the "management-by-exception" principle.

Where basic information is analyzed and interpreted by each management level before passing it up, the higher echelon reports tend to be based on defensive interpretation. Proper development of managerial systems around the computer complex can provide read-outs of different degrees of detail suitable to the management level concerned.

Properly conceived, an engineering task force with a mission to design proper information and control systems represents a most attractive area for improving and streamlining this aspect of the managerial process.—*D. G. Malcolm, Vice President, Western Division, Operations Research Incorporated.*

President's Comments

by **ALEX W. RATHE**

President of the American Institute of Industrial Engineers, 1960-61

The New Industrial Engineer

IF A HOSTILE POWER should wish to cripple this country by hitting some of the people who are important in the future development of the United States, any major AIIE audience would be a choice target. This is so not just because there are so many Industrial Engineers present but because such a large proportion of our membership represents the *new* Industrial Engineer.

GROWTH—IN NUMBER AND SCOPE

Ours is the fastest growing branch of the Engineering Profession. For the last decade for which complete data are available, Industrial Engineering advanced approximately 350% in the number of practitioners—more than any other group; following, with an increase in the magnitude of 250%, were the Electrical and the Chemical Engineers. In the past two years, Industrial Engineering has moved up to fifth place in terms of entries to engineering colleges.

This growth is significant since it has been accompanied also by a similar expansion of the scope of our work. We are not boxed in anymore in the plant. Industrial Engineering has gone, irrevocably, beyond factory walls. It is establishing itself firmly in such activities as:

.. Design and Sales.
.. Finance and Merchandising.
.. Purchasing, Insurance and Warehousing.
.. Operating and Top Management.

And it is active in:

.. Manufacturing as well as non-manufacturing industries.
.. Transportation and construction.
.. Service businesses such as real estate and entertainment.
.. Investment and other banking enterprises.
.. Education.
.. Government.
.. Wholesaling and retailing.
.. Agriculture and indeed many other fields.

An Industrial Engineer—and thus a member of AIIE—is, for instance:

.. The Circulation Manager of one of the largest magazine publishers.
.. The Traffic Manager of a chemical company with a multi-hundred million dollar annual volume.
.. The executive in charge of all research services in a giant pharmaceutical firm.
.. A member of President Eisenhower's Steel Panel.
.. The Assistant to the President of one of this country's most outstanding airlines.
.. Heading up a growing number of companies as chief executive.
.. Dean of an engineering college.
.. Etc.

—to mention just a selection of tiny proportion from a big basket of other imposing achievements.

These results have come about on the strength of the Industrial Engineering work which these men have performed. It has given their respective organizations competitive and other advantages which amply warranted these promotions. But Industrial Engineering, while often a powerful link to the assumption of managerial responsibilities, is holding equally rich rewards for those who continue in engineering practice. Such developments are important to the country as a whole; they are even more significant to each individual Industrial Engineer.

The new Industrial Engineer has a selection of opportunities at his disposal which comprise the full panorama of human activities. The horizons in our field are unlimited. They are the natural outcome of the near-revolutionary developments which are taking place in this generation. We need think only of such advances as have been accomplished in the fields of:

.. Plastics.
.. Antibiotics and other "miracle drugs" which have conquered many physical and mental diseases.
.. Electronics.
.. Communications—instantaneously to any point on this world.
.. Transportation.
.. And dozens of other significant milestones in the advance of Science.

The haunting question at the threshhold of the "Soaring Sixties" is: "Who is going to latch on to this Golden Wheel of Fortune?". I hope I may be pardoned when justifiable pride as the President of the fastest growing engineering society makes me answer this question unhesitatingly as: "Our Members!"

AIIE'S PLANS FOR 1960-61

And it is precisely toward that end that the American Institute of Industrial Engineers is geared. The accomplishments of previous administrations have constructed a foundation of such strength that building upon it to ever greater heights is an obligation and an honor. In planning the operating program of AIIE for 1960-61, attention has been focused upon four major areas.

1. Service to the Individual Member is of course our first concern. Preparations are well underway for ever better regional and national conferences and meetings. New types of events are being designed about which the *Journal* will report further as the work is completed.

A Technical Programs Committee has been set up. Its purpose is the maintenance of a lookout for new opportunities in Industrial Engineering which are beginning to prove themselves in their early applications.

The *Journal of Industrial Engineering*, already the envy of many editors, is getting set for an even more ambitious program. Subject at this point only to approval by the Board of Trustees, of recommendations unanimously agreed upon in the Executive Committee, you may expect:

.. Wider coverage of interesting developments within the profession and within AIIE.
.. A balance between papers of theoretical impact and stories of significant practical applications on the strength of a longer range topic allocation schedule.

In addition, the Publications Division of AIIE will begin special series as companions to the *Journal*. One of these will address itself specifically to management aspects; another will probably concern itself with special research results which have the promise of practical significance.

The Membership Board of Review is the watch tower for the quality of AIIE membership. Its aim is to stand guard over the strict requirements which are a prerequisite to admission to the Institute. Its work will contribute materially to showing that membership in an organization with top notch requirements is a personal asset of formidable value.

A new Ethics Committee will prosecute, on behalf of the chapter involved, improper practice in the pursuit of Industrial Engineering work. A separate story in a later issue of the *Journal* will bring you further information.

From the many other plans, I should like to single out just one, namely that concerning a new series of services for the individual member which is being initiated under the heading "Professional Development."

The secret of success in Industrial Engineering has been our recognition that there will always be a better way. This applies to the use of equipment, of space and of any other resource—material, economic or human. Why should we not apply this principle of the never-ending search for improvement to our own information, knowledge and skills?

AIIE is starting this sector by a program for the young engineer. The first few years out of school are often among the hardest; things do not always look in reality the way they pictured themselves as we heard about them in the classroom. A program, based on ECPD studies of many years, will be made available to every Chapter which is ready to appoint a competent officer to administer it within its community.

But professional development is needed well beyond the first few years. With a respectful bow toward the University of California, may we borrow its deeply meaningful admonition that this is a matter of "life-long learning." In these years of steeply climbing progress, we have to run fast just to stand still. To enable every one of us to better keep up with the many new tools and techniques, thoughts and concepts in Industrial Engineering is the mission of another part of this Professional Development program of AIIE.

Then there is the matter of professional registration and licensing. Accelerated attention will be given to these problems which can be tackled most successfully only on a State-by-State basis. Plans are currently being developed which, we sincerely hope, will help each Chapter improve the registration picture on behalf of the Industrial Engineer where such developments are still desirable.

May I add just one remark concerning Industrial Engineering studies in the colleges. Our Education Committee has already begun a program for the strengthening of the Institute's participation within the ECPD curriculum accreditation procedure. The first session of this undertaking took place in Dallas in May; the second at Lafayette, Indiana, in June; others will follow.

2. Services to Chapters constitute the second area of

special effort by your administration. Offices have been set up to assist every one of our local groups whenever it requests service on problems such as:

.. Chapter operation and organization.
.. Programming.
.. Chapter and membership expansion.
.. Community services.

Particular attention is being devoted to Student Chapters. Plans envision the introduction, for instance, of Leadership Training for Student Chapter Officers; this will help in the conduct of their own activities. It should also constitute a practical apprenticeship for later use in the Senior Chapters.

Based upon the outstanding success of the first Student Chapter Regional Conference in May in Dallas, additional events of this type are being prepared for 1960-61.

3. AIIE operations: May I add a few words about our internal administration. During the Dallas Conference, a total of fifteen Officer Work Sessions was held. In each, plans for all major types of AIIE activity were discussed in detail and fitted together so that efforts in one area of Institute operations will support related ones in other sectors most effectively.

Additional policy and procedure manuals are being established; the organization manual of the Institute is being revised; the chapter development program has already been sharpened up again on the strength of experiences during 1959-60. The purpose of these and similar efforts is the opportunity to pass operating experiences on to our successors in office and to filter out not-so-good practices which are bound to hide, in isolated spots, in any organization which is growing as sharply as AIIE.

Our Long Range Planning Committee is studying the requirements which business and other employers of Industrial Engineers are likely to make upon us in 1975. Although that date seems, at first look, to lie far in the future, it is really just fifteen years away.

AIIE activities will benefit also from one area of Industrial Engineering practice in business where it has been unusually successful; this is the possibility of still further improvement of the cost picture for all Institute operations.

Communications, between officers, with chapters and members, are being improved, Newsletters by the Vice Presidents expanded, and bulletins by the Executive Vice President and the President strengthened. Previous administrations showed us how these things could be done; on the basis of their experience, we hope you will conclude, perhaps as early as by the end of this year, that we have learned well from the example of our predecessors and of every officer and member in the field.

Even a brief discussion of our internal operations would be incomplete if I did not mention the consolidation of headquarters operations, in New York, under the direction of E. Paul Lange, our Executive Secretary. His association with AIIE guarantees success and promises steep progress. With the help of his charming as well as efficient Assistant, Mrs. Ruth M. Dennis, every one of us will find headquarters a source of support and assistance as never before.

Permit me one word of caution, however. Work is being transferred to New York, first, from Columbus which has been our home for all the twelve years of AIIE's life span; beyond that, a number of functions concerning our publications activities are moving from Atlanta to New York, too. This is bound to bring some kinks.

May I urgently plead for your indulgence until the gremlins have been banished from AIIE headquarters for keeps. To be perfectly blunt, this is not possible overnight. It will take a few months. With your understanding help, the transition period could be shorter. Until it is over, please bear with us. We had the choice of allocating a larger proportion of AIIE income to avoid many otherwise inevitable transition problems or of earmarking such funds for more services to chapters and members. We did the latter because AIIE exists to provide, first of all, services to the Industrial Engineering profession.

4. External Relations: Our professional relations will continue to gain strength fast. Fully recognized now for a couple of years as a constituent member of Engineers Joint Council, AIIE will participate in all EJC activities which are of interest to our members.

Discussions have been started with other organizations aiming at the possibility of closer cooperation with such groups as, for instance:

.. The American Society for Quality Control (ASQC).
.. The American Institute of Plant Engineers (AIPE).
.. The Systems and Procedures Association (SPA).
.. The American Society for Engineering Education (ASEE).
.. The Engineers' Council for Professional Development (ECPD).

Extensive attention will be devoted to Public Relations. There is no question that a clearer and better picture of Industrial Engineering is desirable for management and the public-at-large. We believe that it is our obligation to create this better understanding of what an Industrial Engineer does and—even more importantly—what he can do. With greater appreciaton of the imposing potential of Industrial Engineering will come still larger demands and wider recognition.

But to capitalize upon such possibilities, each of us most make certain that he is ready for such progress. This means "professional development"; its programs will begin to be ready by the time you read this brief report. But AIIE can only initiate such efforts; it is up to every member to decide whether he prefers to use them or to disregard them in supreme confidence that man-obsolescence can not touch him.

CEILING UNLIMITED

There are many additional activities, already in operation or planned for an early start. Together with those discussed here, the sum total of these efforts aims at the one objective which AIIE has, like any professional society—to service the entire group of its practitioners by serving each member. It is for his *individual* convenience and career that the *combined* resources of AIIE are being harnessed. The higher the reputation of the Institute, the larger are the benefits which each of us derives from belonging to AIIE.

However this is a two-way street. Each individual, each chapter also contributes to the impression which the Industrial Engineering Profession as a whole gives to our colleagues, to management and to the public-at-large. If some commiserate that "Industrial Engineering is not recognized sufficiently," we have to ask ourselves whether our own actions have been such as to merit such recognition. Industrial Engineering exists because of one single proposition—we can help others do things better. How can we expect our employers to let us participate in decisions concerning their business until we show first that we know how to run ours.

Since its start just twelve years ago, AIIE has been able to score mighty advances every single year. As in each preceding period, your current officers will again endeavor to do their best in 1960-61. Can we count upon you to do the same?

RESEARCH INFORMATION

Once a year the Research Information Committee of the American Institute of Industrial Engineers requests that research sources submit research performed in the area of Industrial Engineering. Sources from which information will be solicited are universities, industrial organizations, research institutions, and non-profit organizations, including government agencies and professional societies. These research abstracts are published annually and provide a valuable service to both industry and universities. Research abstracts are to be collected in the areas of: *Work Measurement, Methods, Plant Engineering, Human Engineering, Engineering Economics, Organization Planning, Industrial Statistics, Production Control, Data Processing, Operations Research, Cost Analysis* and *Industrial Engineering Education.*

The committee will appreciate all information on Industrial Engineering research past and present, about which it might gather abstracts. Write: Dr. Jay Goldman, Chairman, Research Information Committee, AIIE, Department of Industrial Engineering, Washington University, St. Louis 5, Missouri.

Professional Relations

A SURVEY OF EMPLOYER PRACTICES AND EXPECTATIONS CONCERNING THE SAFEGUARDS OF PROPRIETARY RIGHTS

A number of recent court decisions focused the attention of the engineering profession on the question of employer-employee contractual relationship as it concerns transmittal and use of engineering knowledge, particularly in the category of so-called "trade secrets." Examples of these included Sarkes Tarzian vs Audio Devices, Inc., (Calif., 1958); Monsanto Chemical Co. vs Miller, (Utah District Court, 1958); and Taylor Iron and Steel vs Nichols, (New Jersey, 1908). Engineers Joint Council feels that a service could be rendered to the engineering profession by studying this problem. This report presents the findings of a study conducted by the Committee on Employment Conditions of Engineers Joint Council.

THE SURVEY

A questionnaire was prepared by the committee and submitted to a list of engineering employers. The list included some 800 companies in major industrial activities that employ significant numbers of engineers, such as electrical, aircraft and machinery manufacturing, petroleum, chemicals, research and development, mining, and engineering service companies.

A total of 206 responded to the poll. Their answers included comments on the implications of the questions. From these an additional evaluation of the picture was possible. These comments came largely from the group which used formal employee agreements to restrict use of certain technical knowledge of a propriety nature.

Pre-Employment Situations

Approximately 44 percent of the respondents indicated that the areas of specific information acquired in previous employment were discussed in employment interviews. The balance, by inference, relied on the general information contained in employment applications to inform them of the background of prospective employees.

In the exploration of prior know-how, two thirds of the employers indicated by their comments that they recognized the existence of a mutual problem in safe-guarding prior confidential information. Only a few of these, however, assumed any responsibility to determine prior employee commitments or to establish any framework whereby employees' knowledge could remain confidential. Eighty percent of the comments assigned responsibility mainly or entirely to the new employees. Only ten percent explored any prior contractual obligation of employees with respect to patents or disclosures of trade secrets.

Employment Agreements

Almost one half of the respondent employers disclosed that they execute some sort of employment agreements covering patent assignments, non-disclosure of proprietary inormation or both. The form varied very widely for context, scope and post-employment limitations expressed in these agreements, exempli-

fied by sample copies returned with the completed questionnaires. The simplest forms carried only the provision for patent assignments on work carried out for the employer during employment tenure. The most detailed covered permanent prohibitions against utilizing any technical knowledge gained during employment for the benefit of others, as well as a commitment to assist the employer for an indefinite period after termination in patent actions arising from employment.

About one half the companies that indicated normal use of employment agreements returned typical examples, and two thirds included comments on agreements in their questionnaire returns. After review of these comments and examples, the Committee found that 50 percent contained clauses limiting disclosures of proprietary information as well as clauses providing for cooperation in obtaining patents.

The wide use of employment agreements to protect the current employer, and the rare investigation of prior agreement obligations at the time of employment, points up an evident reliance on the engineer's responsibility to determine largely for himself what information he can carry and use from job to job. However, such agreements can and have formed the basis for legal actions with both the engineer and the new employer as defendants.

Confidential Information

Because of the difficulty in defining "trade secrets" or "confidential company information," the survey inquired into the extent to which this information is defined or brought to the attention of the employee to make specific the frames of reference during his employment. The response to this section of the questionnaire showed that while half of the employers felt their areas of confidential information were generally defined to the employees concerned, only 20 percent gave specific guidance to individuals in this matter. The comments indicated a general attitude that reliance was again placed almost solely on the individual to distinguish between proprietary and general information.

About one third of the respondents used termination interviews to generally remind the employee of obligations covered in his employment agreement. Less than 5 per cent of the respondents explicitly covered in termination interviews what to them constituted pertinent confidential information which the employee was bound not to use in the future to benefit himself or others.

Types of Proprietary Information

A basic problem is one of defining the areas of confidential technical information in which the engineering employee may become concerned. These areas concern two categories, patent matters and trade secrets.

Patents

Patent rights are clearly protected by law, and there is little confusion, in the sense of this study, concerning them. Where patent possibilities are considered to arise from technical employment, assignment sections of employment agreements are drawn up which are relatively straightforward and which, in general, cover the obligation of the employee to:

1. Disclose to his employer any patentable discoveries made in the course of his employment.
2. Assist the patent agents of the employer in the filling and prosecution of patent applications on such inventions.
3. Assign the resulting patents to the employer.

Certain of the agreements cover an obligation of the terminated employee to sign patent applications and assignments on discoveries made during his period of employment. Such obligation generally runs for an indefinite period following the termination date. All expenses incurred in such post-employment-patent activity are assumed by the employer.

A few of the agreements provide for the release of an invention to the employee at his request if its field of application is outside the employer's area of interest.

The disclosures and assignments implicit in implementation of patent agreements clearly imply the relinquishment of personal claims of the employee in these matters.

Trade Secrets

An authoritative definition of the term "trade secret" is considered to be as follows:

A trade secret may consist of any formula, pattern, device or compilation of information which is used in one's business, and which gives him an opportunity to obtain an advantage over competitors who do not know or use it. A substantial element of secrecy must exist, so that except by use of improper means there would be difficulty in acquiring the information. Some factors to be considered in determining whether given information is a trade secret are:

1. The extent to which the information is known outside of the business.
2. The extent to which it is known by employees and others involved in business.
3. The extent of measures taken to guard the secrecy of the information.
4. The value of the information to the holder and to competitors.
5. The amount of effort or money expended in developing the information.
6. The ease or difficulty with which the information could be properly acquired or duplicated by others.

(Restatement, Law of Torts, Vol. IV, Sec. 757, Liability for Disclosure or Use of Another's Trade Secrets—General Principles, American Law Institute.)

The Questionnaire

Detailed returns to the questionnaire on safeguarding confidential company information are tabulated with the responses.

Questions	*Response*			
	Yes		*No*	
	No.	*%*	*No.*	*%*
1. At the time of employment interview, do you specifically discuss with engineers the areas of information gained in prior employment that he may properly make available in his new employment?	91	44	115	56
2. Are your company's trade secrets, or developments which may lead to trade secrets, defined for engineering employee guidance at any time during employment?	112	54	94	46
3. Is a definition of restricted company information reviewed with the employee at termination to ensure that a clear understanding exists for limitation of possible future disclosures by the engineer?	65	32	141	68
4. Does the company utilize contracts with engineering				

Questions	Response			
	Yes		No	
	No.	%	No.	%
employees to restrict use of company - acquired knowledge either during or after the term of employment?	99	48	107	52

Excerpts from Selected Comments on Trade Secrets

The obvious act must be faced that in many cases an engineer is hired for a new job because of his experience on previous jobs. We have found no perfect way of spelling out what a man may disclose as part of the skill that he has mastered in a previous job as distinguished from specific knowledge that may or may not be of confidential nature . . . we will be intensely interested in seeing any results you may obtain from this survey. It could be quite helpful to both the engineer and the engineering employer if there was some general agreement on the proper and ethical way to handle this very controversial matter. There probably will always be a conflict between the company's rights and the individual's rights, but this conflict can be minimized by a standardized set of rules on the subject.

•

The loss of technical information and experience to departing employees is a problem that has become of considerable concern to us . . . we have lost to them considerable technical information which they have removed not only through acquired experience but also through specifications, standards, etc. that they later make use of in direct competition with us.

•

In the past we have not formally explained and defined what we consider as confidential information which is protected by employer-employee contracts. Reliance has been placed on the employee's knowledge that he has signed a contract prohibiting the use of a disclosure of such information and the day to day instruction and guidance given by supervisors. Most employees come to know what the company regards as secret and confidential. We are presently adopting a plan whereby secret and confidential information will be more fully explained and defined to the employee at the time he signs the employment contract. The fact that he signs such a contract and its nature will be reviewed to each departing employee during his termination interview. Our anticipated change in handling this matter has not resulted from any difficulty experienced but rather as a result of greater awareness of the problem gathered from the growing number of literature discussions and cases litigated . . . In respect to time . . . we feel that so long as the information remains secret or confidential and important to us, the employee has no right to disclose or use it. Obviously its value decreases with time, as usually does its classification.

•

In our experience it is usually fairly easy for the engineer to sort out the two types of information and we have had no serious difficulties in this area . . . the individual engineer must distinguish between information which is actually confidential and that which is the normal stock and trade of the engineer . . . we have had some scattered instances in which the former employees have apparently disclosed information which we have considered confidential but these have been rare enough that we have not considered this a major problem.

•

We employ most of our engineers directly from college so that they have no previous experience . . . we make no demands to protect our interests after the engineer leaves our employ . . . the usual demands to do this are unenforceable and serve mainly to incite resentment on the part of the individual . . . part of the compensation of an engineer is his training experience gained during employment . . . we do restrict company material that may be carried away in form of reports and laboratory notes . . . we are generally favorable to an engineer being permitted to retain copies of reports he has prepared. Obviously the information is in his head and it is an effective gesture of good will to let him take it on paper.

•

Generally speaking, over the past twelve years we have adopted the philosophy that one keeps out more than he keeps in when he closes the doors of his research. For this reason we have been rather open with the developments and discoveries made in our organization . . . since the advent of the weapon systems concept, however . . . the knowledge which we have disseminated in our specialty is being used by the prime contractors . . . within their own companies. . . . Because of this, we have been more guarded in recent years with our technical know-how and developments. . . . We have not yet instigated a system of classifying company information.

•

We have no formal definition of the company's trade secrets . . . employees have a general understanding of what constitutes trade secrets and company confidential information. We have had no difficulty over a misunderstanding.

•

We are more interested at the time of employment interview in the over-all competence, versatility, and diversified background of an individual rather than specific areas of information he might have gained in prior employment . . . to date we have never had to take any positive course of action to withhold the value of technical knowledge.

•

No formal procedure is adopted whereby the employee at date of original employment, or exit from the company's service are briefed on their responsibility to their present or former employers concerning the utilization of engineering or other confidential information . . . administratively such action would not appear to be feasible or desirable. However, every employee is required to sign the patent agreement.

•

As a practical matter, we have found that lasting protection can be given to this sort of thing only by attempting to establish a patent position on the subject . . . when an engineer leaves our employ, we do not require that he sign any agreement to limit the ideas, or information or know-how that he has gained with us.

•

We have established internal controls for the protection of our position on technical developments by act of filing patent applications. Further, we feel that members of our technical staff enjoy a professional status that guides and determines their conduct and avoids conflicts of interest . . . we do not have trade secrets in the usual sense, such as those that might be found in certain manufacturing concerns . . . however, our technical developments prior to filing of patent applications or obtaining patents might be considered as trade secrets.

•

It is generally assumed that engineering employees understand the ethics of the profession well enough so that specific definitions of what might be considered trade secrets would not be essential. However, where an invention which may result in granting of a patent is involved, the engineer has been instructed that disclosures shall not be made until patent application has been filed or found to be justified.

•

No special effort is taken to withhold the value of technical knowledge developed by the engineer during his course of employment, except as contained in our patent agreement.

Our employees are sufficiently aware of the importance of keeping our technical information confidential and do not require any special discussion of this point on termination of their employment.

•

As long as there are no legal entanglements, such as patents, publications, etc., we would logically expect to cash in on their experience. . . . What they develop which we find to be novel inventions we patent or attempt to patent.

•

When we have an employee who has left another company, we expect him to use all the talent he has acquired academically and practically so long as moral ethics are not violated. When employees leave us we expect them to conduct themselves in the same way and sincerely believe that they do.

•

We have no policy regarding the utilization of employees' know-how acquired in previously held positions or to withhold the value of technical knowledge developed by the engineer during employment with us, except that we do not permit employees to take copies of drawings, reports, specifications or similar material with them upon termination without permission.

•

We fully appreciate that you can write very stiff contracts in such a situation but frankly feel that this is very difficult to enforce. We rely upon the integrity of the engineer to reveal to us those things which we mutually agree can ethically be disclosed if pertaining to information gathered in prior employment.

•

While it is expected that all engineers will adhere to the professional code of conduct no legal commitments are exacted . . . at the time of employment interview the employee's qualifications are reviewed, but no special effort is made to determine restrictions occasioned by his previous employment.

•

In our experience there is little that can be done to prevent an individual from utilizing know-how acquired with us after being hired by a competitor. Obviously his value to either us or the competitor is based on his accumulated knowledge and experience.

•

We do not expect to make use of knowledge of a secretive nature which employees acquired at other employment . . . we expect a gentlemen's agreement in reverse when the employee leaves our organization.

•

We rely primarily on the ethics and honesty of the individual.

•

During the employment interview an effort is made to determine with comparative preciseness the area of competence of the applicant. Inquiry is also made to determine if the applicant is under contractual obligation to his former employer not to engage in research in the area of previous inventions and also list and provide a brief description of all unpatented inventions on the reverse side of his employment contract, which are removed from the operation of the contract.

•

The purpose of this provision is to obtain a civil remedy against the removal from our premises by an employee leaving our employ, of drawings, reproductions or other documents owned by the company and containing confidential information or data relating to the company's business.

•

Where it has appeared that a former employee has been employed by another company to get benefit of knowledge gained at this company, a copy of agreement is sent to new employer. To date the experience has been good.

•

We frequently define for engineering employee guidance areas of secrecy and confidentiality . . . for example, all published reports which contain valuable data or know-how are identified as such so that no inadvertent loss of know-how will result in the handling of such publications. . . . Our plan is to give to the terminating employee during the exit interview a copy of the assignment agreement which was executed at the time of employment . . . calling their attention specifically to the terms of the assignment agreement which they signed.

•

We have only had one case of obvious unethical use of information: (a) Withholding information from company obtained while employed; (b) starting a company in direct competition with work on which the employee was in full charge, and (c) releasing as a product of the new company the product which was assigned for development to the employee while employed here, within such a short period of time that it must obviously have been designed when he was in our employ.

•

We have a very simple criterion which is this: all information received solely and exclusively from one source (client) is held confidential and used only in connection with our relations with that particular source (client). When such information becomes more generally known in the industry so that it comes to us from more than one source the information of itself is no longer confidential, although the connection between such information and the source (client) remains confidential.

•

Every engineering employee . . . is instructed not to disclose confidential information or performing services for a client to any of the client's competitors unless a formal release of this information has been obtained.

•

Trade secrets, or developments which might lead to trade secrets, are, in theory, disclosed and discussed with the particular employees who may have to deal with those secrets or developments. As a matter of practice, however, these discussions do not always take place.

Details of mechanical development in unique equipment or process applications on any specific project defined as confidential are considered restricted during the course of employment. Employees are so informed by verbal communication rather than a formal contract.

•

In most cases employees that come to us with prior knowledge are placed in positions which do not invite the use of specific knowledge from any former employment . . . we expect them to use the same ethics while working for us that we would ask them to practice in dealing with information acquired here should they later take employment elsewhere.

•

Engineers Joint Council is a federation of engineering societies whose membership totals 300,000 engineers. One of the Council's primary objectives is to advance the general welfare of mankind through the resources and creative abilities of the engineering profession, and pursuant thereto to promote cooperation among the various branches of engineering.

The Survey on *Employer Practices Concerning the Safeguarding of Proprietary Rights* was conducted at the suggestion of the EJC Board of Directors and prepared with its approval. Single reprints are free. Costs of bulk quantities are available on request. ENGINEERS JOINT COUNCIL, 29 West 39th Street, New York 18, N.Y.

Institute Interests

CALENDAR

October 10-12: Operations Research Society of America Eighteenth National Meeting, Statler-Hilton Hotel, Detroit, Michigan. Write: George O'Brien, Touche, Niven, Bailey and Smart, 1292 National Bank Building, Detroit 26, Michigan.

October 10-12: International Systems Meeting, sponsored by the Systems and Procedures Association of America, Hotel Commodore, New York, N.Y. Write: David Merriman, President, Systems and Procedures Association, 4463 Penobscot Building, Detroit 26, Michigan.

October 10-14: Product Planning and Development Course Number 7521-02, Hotel Astor, New York, N.Y., sponsored by American Management Association.

October 17-21: 1960 Philadelphia Metal Show (42nd National Metal Congress and Exposition), Convention Halls and Bellevue-Stratford Hotel, Philadelphia, Pa. Write: James C. Nelson, G. M. Basford Company, 60 East 42nd St., New York 17, N.Y.

October 20-22: Institute of Management Sciences, Seventh Annual International Meeting, Henry Hudson Hotel, New York, N.Y. Write: R. M. Thrall, Department of Mathematics, University of Michigan, Ann Arbor, Michigan.

November 14-18: ASTE 1960 Western Tool Show and 28th Semiannual Meeting, Sports Arena, Los Angeles, California. (Technical sessions—Ambassador Hotel, Los Angeles, Calif.) Write: Harry E. Conrad, Executive Secretary ASTE, 10700 Puritan Avenue, Detroit 38, Michigan.

November 27-December 2: American Society of Mechanical Engineers Annual Meeting, Statler-Hilton Hotel, New York, N.Y. Write: L. S. Dennegar, ASME, 29 West 39th St., New York 18, N.Y.

December 26-31: One Hundred Twenty-Seventh Annual Meeting, American Association for the Advancement of Science, Philadelphia, Pennsylvania.

April 12-14, 1961: Purdue University's third Symposium on Information and Decision Processes, Purdue University, Lafayette, Indiana.

CHAPTER DEVELOPMENT PROGRAM

Winners were announced at the Annual Conference Banquet held in Dallas, Texas on May 12, 1960. First place award went to the Milwaukee Chapter. Bob Dimberg, past-president of the chapter and incoming vice-president for Region VIII accepted the FRANK F. GROSECLOSE AWARD on behalf of his chapter. Clarence J. Allen, chapter president was unable to attend. Previous winners were Great Salt Lake in 1958 and San Diego in 1959.

Listing of other award winning chapters follows:

1st Runner-up	San Diego (2)
2nd Runner-up	Atlanta (3)
3rd Runner-up	Dallas-Fort Worth (2)
4th Runner-up	Central Arizona (3)

Regional winners were:

Region I	Central Connecticut (2)
Region II	Lehigh Valley
Region III	Charleston-Huntington (3)
Region IV	Atlanta (3)
Region V	Southern Ontario (2)
Region VI	Cleveland (3)
Region VII	Nashville (2)
Region VIII	Milwaukee (2)
Region IX	Dallas-Fort Worth (2)
Region X	San Diego (2)

Chapters qualifying for an "Award of Excellence" were: (In addition to the above)

First Award:

Cincinnati	San Antonio
Birmingham	Wichita*
Boston	East Texas
Rocky Mountain	Southwest Connecticut
Twin City	Naugatuck Valley**

Second Consecutive Award:

Columbus	Chattanooga
Tulsa	Oklahoma City
Los Angeles	Albuquerque Area
Savannah	Metropolitan New Jersey
Pensacola	Long Island
Central Indiana	Evansville
Niagara Frontier	

Third Consecutive Award:

Dayton
Great Salt Lake
Central Arizona

NOTE:

(2) Denotes two consecutive years for "Award of Excellence."
(3) Denotes three consecutive years for "Award of Excellence."
* Wichita qualified in 1958 but not in 1959.
** Naugatuck Valley is new this year.

BYLAW AMENDMENT

The Board of Trustees in session on Friday, May 13, 1960, took action to amend the AIIE Bylaws—Article IV—Section 6. The original section and the new section, as amended, are quoted below. This amendment became effective on Tuesday, June 14, 1960, in accordance with Bylaw Article VII—Amendments. The changes have been italicized.

BYLAWS—Article IV—Section 6 . . . Board of Trustees

Now Reads:

"Selection of the sites of the National Convention two and/or three years hence shall be made by the Board of Trustees at its meeting at the time of the National Convention each year. Any Chapter desiring to act as host for such National Convention shall make written application to the Director of National Meetings at least 30 days prior to the National Convention. After considering all applications, the Director of National Meetings shall submit in writing his recommendations as to the site, or sites, to be chosen. This report shall reach the members of the Board of Trustees at least 10 days prior to the National Convention."

To Read As Follows:

"Selection of the sites of the National Convention *for future years shall be made by the Board of Trustees at a meeting which shall have been announced at least ninety days prior to this meeting.* Any Chapter desiring to act as host for such National Conventions shall make written application to the *Chairman of the National and Regional Conference Committee at least thirty days prior to this meeting.* After considering all applications, the *Chairman of the National and Regional Conference Committee* shall submit in writing his recommendations as to the site or sites

to be chosen. This report shall reach the members of the Board of Trustees at least ten days prior to *this preannounced meeting.*"

RESEARCH AWARDS COMMITTEE

Two Research Awards were made this year at the National Convention in Dallas. On behalf of the Research Awards Committee of AIIE, Dean Robert Roy of Johns Hopkins University presented the following: a research award of $250 to Ram Vaswani, General Electric Corporation, Louisville, Kentucky; a graduate student award of $250 to C. M. Shetty of the Department of Industrial Engineering, Technological Institute, Northwestern University. (Both of these men have contributed articles to the *Journal of Industrial Engineering* in the past.)

DELEGATION TO U.S.S.R.

An Engineers Joint Council delegation representing United States engineers is spending a month in the U.S.S.R. studying the utilization and allocation of Soviet engineers and technicians.

The six-man delegation left the United States on June 22 and will return on July 23. Under the auspices of the National Science Foundation and the U. S. State Department, the trip is a part of the Soviet-American program of scientific, technical and cultural exchange. The Soviet Ministry of Higher Education extended the official invitation for the mission. A Soviet team will visit the United States at a later date.

Delegates were chosen by Engineers Joint Council on the basis of professional training and experience and their knowledge of engineering manpower. The six represent a cross-section of engineering specialists, engineering education, and economics. They are:

Walter E. Lobo, Delegation Chairman, Consulting Chemical Engineer, New York, N.Y.; R. Russell Beatty, President of Wentworth Institute, Boston, Mass.; Carlton S. Dargusch, Advisor, Engineering Manpower Commission of Engineers Joint Council, Columbus, Ohio; Oleg Hoeffding, Economist, The Rand Corporation, Santa Monica, Calif.; Sydney B. Ingram, Director of Technical Employment, Bell Telephone Laboratories, Inc., Murray Hill, N.J.; and Robert M. Mahoney, Manager, Industrial Relations Development, Union Carbide Corporation, New York, New York.

Engineers Joint Council is a national federation of 21 engineering societies.

Engineers Joint Council delegation to the U.S.S.R.—Seated, L. to R.—Walter E. Lobo and H. Russell Beatty. Standing, L. to R.—Carlton S. Dargusch, Oleg Hoeffding, Sydney B. Ingram, and Robert M. Mahoney.

PERSONALITIES

ASA S. KNOWLES

Asa S. Knowles, Northeastern University president, was made an honorary member of the American Institute of Industrial Engineers at a meeting of the Boston Chapter on Monday, May 17 at the Hotel Lenox, Boston.

NEW HONORARY MEMBER of the American Institute of Industrial Engineers is Asa S. Knowles, President of Northeastern University, second from left. Presentation was made in ceremonies Monday, May 16 at the Hotel Lenox. Others shown here are (left to right): George H. Martin, president of the Boston Chapter, AIIE; William J. Vallette, national board member-at-large, who made the presentation; and Lionel Griffith, assistant controller of the International Latex Corp., Dover, Delaware, and the principal speaker.

The citation, signed by Frank J. Johnson, National President, AIIE, was presented in recognition of President Knowles' "faithful and distinguished service to, and eminent position in the profession of Industrial Engineering."

Making the presentation was William J. Vallette, national Board Member-at-Large and Director of Industrial Engineering, CBS Electronics.

Mr. Vallette in an announcement of the award, said, "only a small number of nationally-known men, including former President Herbert Hoover, have been selected for this honor since AIIE has been in existence."

President of Northeastern since July 1, 1959, Dr. Knowles previously served eight years as the president of the University of Toledo. He was also founding president of the Associated Colleges of Upper New York and was vice president of Cornell University. He is the author of *Job Evaluation For Hourly and Salaried Workers* and co-author of *Industrial Management, Management of Manpower, and Production Control.*

GORDON J. MURPHY

Recent developments in feedback control theory will be applied to problems of production and inventory-control for the first time, in a research project now being started by Gordon J. Murphy, professor of electrical and Industrial Engineering at Northwestern University Technological Institute.

As recent winner over 20 other applicants for the first research grant of the Foundation for Instrumentation Education and

Research (FIER), Murphy received a $5,000, one-year grant to begin the work.

He plans to develop guides for management, showing how to minimize costs by correctly controlling rate of production and warehousing. At first a simple, limited problem will be studied, but Murphy hopes later to generalize his results for broader use. In the initial problem, assumptions will be: orders filled immediately; standard manufacturing specifications used; fixed review time maintained. Factors considered in the problem will be lead time, shipping time, sampling period, time of sampling, and order time.

To solve the problems proposed, sampled-data theory will be employed, with the mathematical tool being the Z-transformation. This is a special form of the LaPlace transformation, a concept used extensively in feedback control theory for the past 10 years.

Murphy has written two texts, "Basic Automatic Control Theory" and "Control Engineering." He also has done research in automatic control systems, specifically in sampled data, statistical analysis and data processing. Murphy, newly promoted to the rank of full professor, also has initiated new courses in systems engineering and data processing techniques since coming to Northwestern in 1957.

CHARLES F. STEPHENSON

Charles F. Stephenson of York, Pennsylvania, was presented the first Engineer of the Year award of Lincoln Chapter, Pennsylvania, Society of Professional Engineers.

Mr. Stephenson is a charter member of the York, Pennsylvania, chapter of the American Institute of Industrial Engineers. He is president of Stephenson-Walsh and Associates, Inc., York, Pennsylvania, and of Stephenson-Walsh-Hodnick-Bissett-Allan, Ltd., Architects and Engineers in Europe and Africa.

The award contains the following inscription:

For outstanding contribution to:

The advancement and recognition of the Engineering Profession among the public at large,

The body of Engineering Knowledge as evidenced by the development and integration of new designs and techniques for industry and the public,

The community through extensive and unselfish devotion of time and energy to civic, charitable, religious and cultural activities and organizations.

CHARLES F. STEPHENSON (left) shown receiving the Engineer of the Year award of Lincoln Chapter, Pennsylvania, Society of Professional Engineers, presented by HOWARD SLAGLE, State Director of the Society.

LONG ISLAND CHAPTER

The Long Island Chapter o AIIE presented a full day seminar on Practical Work Measurement at the Garden City Hotel, Garden City, Long Island on June 7. Mr. Harold B. Maynard, prominent professional engineer, was seminar leader.

Some of the topics discussed were: "Reduction of Tool Room and Job Shop Costs," "Improving Estimating," and "Planning and Scheduling." The seminar dealt with MTM as it can be applied in the Tool Room, Job Shop, and in Maintenance. It was especially designed for Plant Managers, Industrial Engineers, Tool Designers, Product Engineers and shop supervisors responsible for controlling toolroom, and job shop costs and schedules.

Mr. Maynard, prominent in the international field of scientific management, is president and founder of a firm of management consultants known as H. B. Maynard and Company, of Pittsburgh, Pennsylvania. He is one of the originators of Methods-Time Measurement, and is responsible for the creation and development of many other techniques for production and planning controls, organization, administration, and training. His numerous and outstanding awards and honors, including the Gilbreth medal and the Wallace Clarke medal, bear testimony to his achievements in the field of Engineering. He is author and co-author of four technical books now used in colleges and universities, is Editor-in-Chief of the Industrial Engineering Handbook and is currently Editor-in-Chief of the Top Management Handbook.

METROPOLITAN NEW JERSEY CHAPTER

The Metropolitan New Jersey Chapter has been selected as host for the National Conference and Convention to be held May 17, 18, and 19, 1962. The designation, by the Board of Trustees, was by a 15 to 1 vote, and indicated the great confidence of the Board in our chapter.

The written proposal, setting forth our plans, was prepared by our National Conference Committee, which includes, as chairman, El Rotolo of Arthur Young & Co., Don Rudkin, Merck & Co., Don Olsen, Lehn & Fink Products, and Dan Mandel of the Level-Line Company.

El Rotolo made the verbal presentation at the Board meeting, outlining the reasons why the 1962 Conference should be held in Atlantic City.

ORANGE COUNTY CHAPTER

At our regular May meeting, the new Orange County Chapter was presented its charter, making us a full-fledged member of AIIE. Robert Lockwood, Vice President of the Los Angeles Chapter, made the presentation to Lonnie J. Robbins, first President of the Orange County Chapter.

With the help and advice of Los Angeles, our chapter is off to a running start. We have already started to find new prospective members in the area—men who, for the most part, would not consider membership without a nearby chapter.

SOUTHERN ONTARIO CHAPTER

On Friday April 29, one hundred and ninety-eight management people from many parts of Ontario and Quebec convened at the Lord Simcoe Hotel in Toronto to participate in a one-day "Cost Control Clinic." Sponsored by the Southern Ontario Chapter of

LONNIE J. ROBBINS (left) receiving new Orange County Chapter Charter from ROBERT LOCKWOOD, Vice President of Los Angeles Chapter.

the American Institute of Industrial Engineers, the clinic was conducted by Phil Carroll, well-known Industrial Engineer and author from Maplewood, New Jersey. Seventy different companies were represented at the clinic.

In a forthright and dynamic manner, Mr. Carroll discussed the following topics: "Profit Leaks—How to Find and Stop Them," "Overhead Costs—How to Control Them," "Overhead Budgets—How to Develop Them." and "Indirect Labor Costs—How to Measure and Control Them." Qualified by many years as a management consultant, Mr. Carroll presented and illustrated his material in a realistic and logical manner which was enthusiastically received by the participants.

In discussing Profit Leaks, Mr. Carroll suggested that twenty percent of the costs in industry were attributable to management errors. He classified such errors as failure to plan, failure to specify, and failure to follow up. In most job shops, he said, a gold mine in inventory is waiting between operations owing to these common management errors. He further observed that the outstanding defect in conventional Profit and Loss statements is that they show profits made but not profits lost.

For effective use of overhead budgets, Mr. Carroll said that managers must "get away from ratio thinking." He emphasized the importance of determining trends in overhead budget items and explained a method of developing a variable overhead budget. He pointed out that most overhead is "people cost," and stated that standards for performance must be established for indirect workers. If standards or goals are not established by management, the people will set their own. People can spend money, thus only people can save money—systems can only cost money. Thus, people must be taught to work in an effective way with a view toward the objectives of the company, and must be compensated in such a way as to encourage the continual improvement of their jobs.

Mr. Carroll went on to point out that every advancement in management raises overhead both in amount and in the rate. In fact, a low overhead ratio could mean that, the "tools" of better management are not being used. Thus to attempt to hold down the overhead ratio is to deny progress.

The primary value obtained from cost information is its contribution to management decision-making—price bears no relationship to cost.

Mr. Carroll classified indirect labor as necessary, optional, or luxury. He stressed the need for measurement of indirect labor for incentive payment purposes, overhead reduction and for determination of product costs. While measurement of indirect work has always been considered difficult, Mr. Carroll observed that much indirect work is highly repetitive and readily measurable. An example is the punching of cards for data processing equipment. He described the use of the electronic computer in business as a way of "shuffling our errors more rapidly."

Mr. Carroll claimed that most cost records "aren't worth the paper they're written on" and concluded by stating that managers must know more accounting than accountants in order to prescribe the kinds of information required for better decisions.

The sessions were illustrated with colored slides and participants were issued printed problem sheets to permit practice in applications of the concepts discussed. Four enthusiastic question-and-answer periods were held during which Mr. Carroll discussed cost problems as well as problems of time study and incentive systems.

The Southern Ontario Chapter, the first in Canada, now has about 100 members. Interest expressed at the clinic indicates a continuation of the rapid growth of the chapter experienced since its inception two years ago.

YOUNGSTOWN CHAPTER

Our meeting for the month of May was a very special evening, planned and carried out with great success. Members and guests enjoyed cocktails, dinner, and dancing in addition to the ceremony of installation of new officers, and a most interesting talk by Mr. Edwin Paulie.

Mr. Paulie, a graduate of Washington and Jefferson College, a former coach, college instructor, and salesman, is presently Supervisor of Management Training at the Imperial Works in Oil City, Pennsylvania, and a leading instructor in the famous Dale Carnegie courses. His talk for the evening was entitled "What's In It For Me?"

1960 WESTERN REGIONAL CONFERENCE

A I I E

Salt Lake City, Utah

Hotel Utah

September 30-October 1

"Concepts to Meet the Challenge of Modern Management"

Sponsored by—Great Salt Lake Chapter

PLAN NOW TO ATTEND

Write: **H. D. McTague, *Chairman***
1960 Western Regional Conference
P.O. Box 510
Provo, Utah

Recent Readables

NEW PUBLICATIONS

"Planning and Justifying Capital Expenditures"

A Summer Symposium on "Planning and Justifying Capital Expenditures" was held at Pittsburgh, Pa., on June 13-14, 1959. It was sponsored by the Engineering Economy Division of the American Society for Engineering Education and the Engineering Economy Research Committee of the American Institute of Industrial Engineers.

Topics covered were: Capital Budgeting and Project Justification, Post Auditing, Estimation of Working Capital Requirements for Long-Range Planning, Effects of Taxes on Investment Decisions, Evaluating Uncertainty.

Copies of the papers and discussions may be ordered from:

The Engineering Economist
Stevens Institute of Technology
Hoboken, New Jersey

The price is $4 for members of ASEE and AIIE, for educators, schools and all libraries, and for those who attended the Symposium, and $10 for others.

AUTOMATION

"IBM Automates Management," K. W. Bennett, THE IRON AGE, *page 29, June 2, 1960.*

Management Operating System can schedule production, regulate inventory, forecast sales, and initiate purchase orders. It can even evaluate the success of the entire operation.

"Mechanization: An Uneasy Issue," Labor Editor, ENGINEERING NEWS RECORD, *page 89, May 5, 1960.*

An extremely pertinent and interesting discussion of one of the most important questions facing America today—socially and industrially. The effects of recent Supreme Court Rulings and Labor and Management concepts of the problem are discussed. *(John M. Barksdale—Ethyl Corporation)*

COST CONTROL

"Cost Control, Top Plants of 1960," FACTORY, *page 144, May, 1960.*

How the Top Ten of 1960 control and improve costs

GENERAL

"Top Plants of 1960—Maintenance," FACTORY, *page 166, May, 1960.*

Answers by Top Tenners to 6-odd questions posed by *Factory* on the management of maintenance.

"Plant Operations Case Book," FACTORY, *page 273, May, 1960.*

A multitude of ideas for improving operations of various types. *(B. M. Bryant—Ethyl Corporation)*

"Executive Study Group Finds Maintenance Shedding Old Ways," FACTORY, *page 116, June, 1960.*

Now—maintenance men are using Industrial Engineering techniques. Now—maintenance supervisors accept work measurement as a valid tool. Now—maintenance managers are more savvy—no longer fooled by gimmicks. Now—maintenance costs undergo strict accounting scrutiny. *(B. M. Bryant—Ethyl Corporation)*

"Statistics in the Chemical Process Industries—Present and Future," INDUSTRIAL AND ENGINEERING CHEMISTRY, *page 497, June, 1960.*

Statistical plans for experimenting and problems they help people solve. *(B. M. Bryant—Ethyl Corporation)*

"Business Education For Engineers," W. G. Dreson, MECHANICAL ENGINEERING, *page 63, March, 1960.*

Economics in engineering education. This chapter from a recent book discusses current trends—a study of university—college program in business administration. *(B. M. Bryant—Ethyl Corporation)*

"Why Engineers Work," Eugene Raudsepp, DESIGN, *page 100-109, February 4, 1960.*

Characteristic factors of the kinds of jobs engineers seek and keep. *(A. L. Friedrichs—Ethyl Corporation)*

"How to Prepare Charts and Graphs," Ray Marien, THE OFFICE, *pages 82-89, July, 1960.*

Time has always been synonymous with money and that was never more true than it is today. To save time and money, many companies have established chart and graph-making departments. Here data are taken from lengthy tables of statistics and converted to easily understood art work.

"Managing Your Manpower," Lawrence Stessin, DUNN'S REVIEW, *page 154, June, 1960.*

The unhappiest man in your company is not the fellow who was turned down for a raise yesterday. Instead, he is the one who makes pretty good money, enjoys lots of benefits, and is usually treated with kid gloves. He is the engineer or scientist on your payroll—presently, a million strong in industry and growing at eight times the rate of the labor force as a whole. These professional people are presenting management with one of the most baffling and complex personnel problems yet faced. This article presents an intelligent discussion of the problem and possible solutions. Some measures being tried by industry as a solution to the problem are discussed. *(J. M. Barksdale—Ethyl Corporation)*

"Revitalizing The Engineering Organization," Philip Marvin, DESIGN, *page 170, May 12, 1960.*

An outline of a practical program for putting technical activities back into shape when they become stale and tired. *(A. L. Friedrichs—Ethyl Corporation)*

"Engineering Semipro? Part I," DESIGN, *page 24, May 12, 1960.*

First in a series of articles dealing with the engineering technician. The articles are based on the findings of an opinion study of industrial and union leaders, educators, engineers, and technicians. This article is concerned primarily with the definition and job capabilities of the technician. *(A. L. Friedrichs—Ethyl Corporation)*

"Active Microfilm Systems," T. R. Sainsbury, DESIGN, *page 104, May 26, 1960.*

In addition to preserving engineering drawings, microfilm is bidding for bigger jobs in daily use. From punched cards which carry single frames of film, new machines and procedures quickly provide working size enlargements, singly or in quantity. *(A. L. Friedrichs—Ethyl Corporation)*

"Reduce Costly Down Time," H. M. Schenk, CHEMICAL ENGINEER, *page 164, April 4, 1960.*

This article illustrates the method of setting up a preventive

maintenance schedule for instruments. *(B. J. Grady—Ethyl Corporation)*

"Employer Teamwork Can Cut Your Costs," Robert Newcomb and Marg Sammons, ENGINEERING NEWS RECORD, *pages 43-45, June, 1960.*

Cost reduction, one of management's perennial goals, is an urgent necessity in today's competitive race. How to "sell" it in the shop and office? The authors cite excellent "working" examples to answer the question.

"Engineering Department Organization," S. W. Brossman, ADVANCED MANAGEMENT, *pages 16-17, May, 1960.*

The trouble sometimes lies in the obvious fact that the advance engineers are interested mainly in the idea, and the product engineers are interested mainly in the product.

"Buying Becomes Part of Selling," THE IRON AGE, *page 100, June 2, 1960.*

DoAll Company has made its purchasing department a part of its over-all selling operation. The system keeps costs low and allows a close check on inventories at all distribution points.

INVENTORY CONTROL

"Scientific Inventory Control," John M. Mayer, Paul Taylor, CHEMICAL ENGINEER, *page 140, June 27, 1960.*

This article illustrates a method for calculating the minimum stock level and cost of maintaining an item in stores. *(B. J. Grady—Ethyl Corporation)*

MATERIAL HANDLING

"Fuel Cells—Almost Here," Dick Dietz, MATERIAL HANDLING ENGINEERING, *page 50, July, 1960.*

The question about fuel cells is not whether they will work but when they will be ready for use. Some advantages of their application to material handling equipment, especially to fork trucks, are discussed. *(N. E. Sparks—Ethyl Corporation)*

"Material Handling, Top Plants of 1960," FACTORY, *page 154, May, 1960.*

A four-page review of ideas applied to a multitude of handling situations of the 1960 Top Ten. *(B. M. Bryant—Ethyl Corporation)*

PLANT LAYOUT

"Three New Tools for Better Plant Layout," FACTORY, *page 101, June, 1960.*

Really new plant layout techniques don't come along every day. When three emerge at once, it's news. *(B. M. Bryant—Ethyl Corporation)*

"New Line Doubles Foundry Yield in Half the Floor Space," G. Charles and A. J. Kipp, THE IRON AGE, *pages 101-103, April 28, 1960.*

Management often becomes wary whenever heavy capital investment seems to be needed for added floor space and increased production—and rightfully so. Here's a foundry that uses automation at no great expense to attain these goals.

QUALITY CONTROL

"Management Looks at Quality Control," G. A. Peck, QUALITY CONTROL, *page 42, May, 1960.*

A brief history of quality control and its role as seen from management's viewpoint. *(A. L. Friedrichs—Ethyl Corporation)*

SYSTEMS AND PROCEDURES

"Records Management with a Positive Approach," J. M. Thom, THE OFFICE, *pages 14-36, May, 1960.*

The traditional approach has been to accent the negative: eliminate or destroy. This corporation emphasizes the service aspect.

"The Consolidated Functions Concept," Al N. Seares, ADVANCED MANAGEMENT, *pages 22-28, June, 1960.*

With the general acceptance of decentralization as a basic management operation, there must be a well-organized control procedure to appraise efficiency. The author explains his solution—an impartial, objective control center.

"How Statistical Sampling Improves Office Operations," Benjamin J. Mandel, THE OFFICE, *pages 77-81, July 1960.*

Scientific statistical sampling can aid management extract, often quickly and inexpensively, valuable factual information from office records and activities. This can aid in making rational decisions regarding the office staff and its procedures.

BOOKS

EXECUTIVE DECISIONS AND OPERATIONS RESEARCH, *by Miller and Starr, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1960, 446 pages.*

OPERATIONS RESEARCH AND SYSTEMS ENGINEERING, *by C. D. Flagle, W. H. Huggins, R. H. Roy, Johns Hopkins Press, Baltimore, 18, Maryland, 1960, 888 pages, $14.50.*

ELEMENTARY STATISTICS, *by Paul G. Hoel, John Wiley and Sons, Inc., New York, 1960, 261 pages, $5.50.*

STATISTICAL QUALITY CONTROL HANDBOOK, *Second Edition, published by Western Electric Company Inc., New York, 1958, 328 pages, $7.50.* (Available only from: Superintendent, Quality Assurance, Western Electric Company, Inc., 195 Broadway, New York 7, New York.)

PROBABILITY—AN INTRODUCTION, *by Samuel Goldberg, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1960, 322 pages, $7.95.*

MODERN PROBABILITY THEORY AND ITS APPLICATIONS, *by Emanuel Parzen, John Wiley and Sons, Inc., New York. 1960, 464 pages, $10.75.*

DYNAMIC PROGRAMMING AND MARKOV PROCESSES, *by Ronald A. Howard, The Technology Press and John Wiley and Sons, Inc., New York, 1960, 136 pages, $5.75.*

EXPONENTIALLY DISTRIBUTED RANDOM NUMBERS, *by Charles E. Clark and Betty Weber Holz, Johns Hopkins Press, Baltimore 18, Maryland, 1960, 247 pages, $6.50.*

MATHEMATICAL METHODS FOR DIGITAL COMPUTERS, *by Anthony Ralston and Herbert S. Wilf, John Wiley and Sons, New York, 1960, 293 pages, $9.00.*

ELECTRONIC DATA PROCESSING—SUBJECT BIBLIOGRAPHY OF PERIODICAL LITERATURE 1959, *Lybrand Ross Brothers and Montgomery, New York, 1960, 49 pages.*

DIGITAL COMPUTER PRINCIPLES, *by Wayne C. Irwin, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1960, 321 pages, $8.00.*

ENGINEERING DATA PROCESSING SYSTEM DESIGN, *by Arthur D. Even, D. Van Nostrand Company, Inc., Princeton, New Jersey, 1960, 282 pages, $6.50.*

ADMINISTRATIVE ORGANIZATION, *by John M. Pfiffner and Frank P. Sherwood, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1960, 481 pages, $9.00.*

PRINCIPLES OF BUSINESS ORGANIZATION AND OPERATION, *Third Edition, by William R. Spriegel, Prentice-Hall, Inc., 1960, 592 pages, $10.60.*

PRINCIPLES OF MANAGEMENT, *Third Edition, by George R. Terry, Richard D. Irwin, Homewood, Illinois, 1960, 778 pages, $9.00.*

CHANGING PATTERN OF INDUSTRIAL CONFLICT, *by Arthur M. Ross and Paul T. Hartman, John Wiley and Sons, Inc., New York, 1960, 220 pages, $6.50.*

MEDICAL FEE GUIDE, *Medical Reference Bureau, P. O. Box 1405, Stanford, California, 1959, 563 pages, $20.00.* (An extensive compilation of fees and claim procedures, useful in dealing with workman's compensation and related matters.)

PERSONNEL AND INDUSTRIAL RELATIONS, *by Russell J. Johnson, Richard D. Irwin, Inc., Homewood, Illinois, 1960, 572 pages, $8.40.*

LABOR AND TRADE UNIONISM—An Interdisciplinary Reader, *by Walter Galeson and Seymour Martin Lipset, John Wiley and Sons, Inc., New York, 1960, 379 pages, $6.50.*

SMALL INDUSTRY ADVISORY SERVICES AN INTERNATIONAL STUDY, *by Joseph E. Stepanek, The Free Press of Glencoe, Illinois, 1960, 193 pages, $6.00.*

INDUSTRIAL ESTATES TOOL FOR INDUSTRIALIZATION, *by William Bredo, The Free Press of Glencoe, Illinois, 1960, 240 pages, $6.00.*

THE HUMAN SIDE OF ENTERPRISE, *by Douglas McGregor, McGraw-Hill Book Company, Inc., New York, 1960, 246 pages, $4.95.*

THE NATURE OF SCIENCE, *by David Greenwood, Philosophical Library, New York, 1959, 95 pages, $4.75.*

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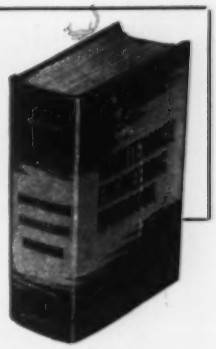

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For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

ADDRESS OF THE SERVICE

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32 West Fortieth Street
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Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1,000	Qualifications required		
						Years of exp.	Age range	Remarks
41	Consulting	Ohio	×	10, 21, 31		5–7		
167	Weapons Systems	Wash. D.C.		50				Ph.D.
213	Air Force	Calif.		15, 32, 42, 43, 44, 53	7.5–	2½–	21–	Repair & Modification
273	Air Force	Utah		11, 13, 18, 42, 43, 44, 53	6.3– 7.5	2–		I.E. Degree
279	Air Line	Ill., Colo., Calif.		11, 13, 18, 41–43, 50–52, 70	6.0–10.0	1–6		
423	Air Force	Ohio		Broad	8.8			I.E. Degree
424	Air Force	Ohio		Broad	4.5– 7.5			I.E. Degree
449	Electronics	Mass.		30, 50, 70	6.0– 8.0	1–5		
464	Consulting	N.J.	×	10, 20, 32–34, 42, 43, 54, 71–73, 92	8.0–12.0	5–	30–36	I.E. Degree
465	Consulting	Mass.	×	Senior Engineer	12.0–15.0	10–15	32–50	I.E. Degree or Equiv.
470	Mining & Smelt .	N.M.		11, 13, 26, 36, 42, 45	5.0–7.0		–45	I.E. Degree Preferred
472	Plastic and Wood Prod.	Va.		11	8.0– 8.5	1–2	–30	MTM Experience(Woodwkg.)
479	Brass Produc s	Conn.		10, 20, 36		1–5		Math. Experience
491	Airline	Ill., Colo., Calif.	15%	11, 13, 18, 51, 70	6.0–10.0	1–5	–40	I.E. Degree Pref.
493	Plumbing Supplies	Ohio		11, 13, 18	7.5– 9.0	7–	30–35	I.E. Degree
494	Electronics	Utah		10–18, 34, 36, 40–46, 91	7.5– 9.0	5–10	30–40	I.E. Degree
499	Electronic Equip.	N.Y.		10, 36	Open	3–		I.E. Degree or Equiv.
503	Electronics	D.C.		30	9.0–11.7	5–		I.E. Degree
506	Railroad	Pa.		11, 13, 31, 36, 42, 43	5.7– 7.2	0–2	24–30	I.E. or I.M. Pref.
507	Railroad	Pa.		31–38, 51–53	7.2– 9.6	2–5	24–35	I.E. or I.M. Pref.
514	Air Force	Ohio	25%	12, 17, 18	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
515	Air Force	Ohio	25%	40	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
516	Air Force	Ohio	25%	32, 37	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
517	Air Force	Ohio	25%	10, 13, 16	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
518	Air Force	Ohio	25%	Broad I.E.	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
519	Automotive Parts	Mich.		10, 11, 13, 19, 26, 36, 38, 42	6.0– 9.0	7–20	30–45	College Degree
522	Ind. Fastenings	Ill.		11, 14, 15, 19, 36, 38, 43, 45, 71	6.0– 7.8	1–3	–35	
524	Utilities	D.C.		10, 13, 17, 37	6.0– 7.0	2–3	28–	I.E. Degree
534	Glass	N.Y.	¼	11, 42, 43, 44, 45, 46, 47	7.0–	5–	30–40	I.E. or M.E. Degree
538	Papermaking	Pa.		50, 51, 52, 53, 54,55	Open	2–5	25–35	M.S.I.E.
539	U. S. Army	Ill.	×	37, 52, 54	8.8– 9.5	3–		B.S. Degree
541	Communications Mfg.	N.Y.		13, 43, 81	7.0–10.0	3–10	30–40	I.E. Degree or Equiv.
542	Electronics	N.Y.		19, 42, 43	5.2– 8.5	0–3		B.S.—I.E., I.M., or M.E.
543	Air Force (Maint.)	Pa.		11, 13, 18, 44, 53, 91	7.5	4–	25–40	I.E. Degree
545	Consulting	Pa.	×	10, 20, 30, 40, 50, 70, 90	8.0–10.0	5–	28–40	M.E. or I.E.
552	Smelt. & Titanium	Canada			7.0– 8.5	5–10		
553	Sugar Refining	Md., La.		11, 36, 38, 43	6.2–9.0	0–5		I.E. Degree
555	Office Machy.	Mich.		11, 30–37	9.6–	3–	30–40	Exp. in System Analysis
556	Office Machy.	Mich.		30	9.6–	3–5		Exp. in Quality Control
561	Navy	S.C.		11, 15, 17, 18, 52, 71, 90	7.5– 8.2	2½–		Degree
563	Needles	Mo.		92	9.0–10.0	8–10	30–	College Graduate
564	Education	N.D.		30, 40, 50	7.5–	8–	40–50	M.S./Ph.D. or P.E.
566	Education	Mo.		10, 30, 40, 50	Open			College Degree
567	Lumbering Mfg.-Cut Parts	La.		10, 30, 32, 33, 40, 48, 94	4.5– 6.5		25–40	
569	Transportation			10, 30, 42, 43, 47	8.4– 9.6	7–	30–	I.E. Degree
570	Transportation			10, 30, 42, 43, 47	7.0– 8.4	4–	20–	I.E. Degree
571	Transportation			10, 30, 42, 43, 47	6.0–	None	20–	I.E. Degree
572	Mgmt. Consultant	U.S.A. & Europe	×	10, 11, 13–18, 21, 22, 91 or 92	Open	5–	30–40	MTM Experience
574	Aircraft Parts—(Mach.)	N.J.		10, 11, 13–16, 18, 36, 91	9.0–12.0	8–12	32–45	Engineering Degree
578	Education	Ohio		50–54			Open	M.S./Ph.D.—M.E., I.E., or Applied Math.
579	Pharmaceutical	Ill.		10, 11, 13, 14		3–5		I.E. Degree or Equiv.
582	Paper	Ga.		43	7.5– 8.5		30–40	B.S. in I.E. or I.M.
583	Plastic Molding	Mass.		11, 13–16, 18, 22, 42	7.2–			I.E. Degree
584	Chemical	Pa., W.Va.		11, 18, 38, 52	7.0–	3–	25–	B.S. Degree
585	Garment Mfg.	N.J.		10	5.2– 5.7	0–2		I.E. Degree
586	Glass Containers	Ind.		10, 11, 13, 14, 16, 21, 31, 36	6.3– 7.5	2–5	22–35	I.E. Degree Ref.
587	Naval Avionics	Ind.		11, 30, 40, 70	6.2– 7.5	2–4		I.E. Degree
588	Printing	Ohio		10, 20, 30, 40, 42, 43	Open	2–7	–30	I.E. or M.E. Degree
593	Metal Working	Mich.		10, 11, 13, 20, 39, 42	10.0–	10–		Engineering Degree
594	Chemical Mfg.	Tex.		11, 30, 32, 34, 43	7.0– 9.5	2–6	27–40	B.S.I.E.
595	Plastics	Ill.		11, 42–46	7.2– 8.4	5–		B.S.M.E. or B.S.I.E.
596	Mining & Refining	Ariz.		11–13, 18, 26, 28, 35, 36, 38, 48	6.5– 9.0		–40	
597	Needle-Plastics	Dela.		11, 14, 15, 19, 22, 26, 42, 48, 91	7.9– 9.5	4–	28–35	B.S.I.E. or B.S.M.E.
598	Needle-Plastics	Dela.		31, 33, 35, 36, 43, 71, 73, 91	7.9– 9.5	4–	28–35	B.S.I.E. or B.S.M.E.

Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1,000	Qualifications required		
						Years of exp.	Age range	Remarks
601	Wood and Plastics	Va.		21	7.5– 8.0	2–3	25–35	B.S. Degree
603	Training	Mich.		30—in Metal Cutting	7.0–	3–5	25–	B.S., M.S., Ph.D. I.E., M.E.
604	Training	Mich.		30—in Plastics	7.0–	3–5	25–	Same as above
607	Elect. Controls	Mass.		30,32,39	10.0–12.0	5–10	–40	I.E. or M.E. Degree
608	Elect. Controls	Mass.		Production Engineer	6.5– 8.5	2–3	25–35	I.E. Deg. with Electronic or Prec. Mech. Assy. Exp.
609	Research & Devel.	Md.		30, 40, 42		8–		B.S.I.E.
610	Research & Devel.	Md.		30		5–		B.S.I.E.
611	Research & Devel.	Md.		30		3–		B.S.I.E.
615	Heat Trans. Equip. Mfg.	Wis.		11, 14, 15, 19, 32, 38	6.6–	3–	–35	B.S.I.E. Pref.
617	Steel Goods Mfg.	N.M.		11, 31, 35, 54, 70	6.0– 8.0	3–5		I.E. Degree
618	Metalworking	Ohio		10, 11, 19, 32	Open	8		B.S.I.E.
619	Metal Casting & Machy.	Minn.		10, 30, 40, 44, 92	9.0–12.0	8–		
620	Food Machy. Mfg.	Iowa		36, 42, 43	6.0– 8.0	5–		M.E. Deg. or 2–3 Yrs. Col.
621	Boats	Mich.		30, 40	6.0– 8.4			
622	Casing Testers	Texas		30, 71		3–5	–35	B.S.I.E.
623	Semiconductors	Mass.		11, 13, 16, 19, 42	8.0–11.0	3–5		
624	Navy	D.C.		44, 49, 54, 70	4.5– 7.5		Open	
626	Mining, Milling, Smelting	Utah		92, 13, 21	7.9–10.7	5–		Engineering Degree
627	Railroad	Md.		11, 35, 36, 38, 54, 70–73	6.5–10.0	3–	25–	College Graduate
628	Paper & Pulp Mfg.	Maine		11, 18, 22, 43, 91	8.0– 9.0	5–	–40	I.E. Degree
629	Electronics	N.Y.		50–55				I.E. or B. A. with Math.
630	Textile & Paper Prod.	Tenn.		10, 11, 13–15, 18, 19, 21, 22, 26, 36	6.0– 7.5	2–3		I.E. Degree or Equiv.
631	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47, 90	7.5	3	20–	B.S. in Engineering
632	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	7.5	3	20–	B.S. in Engineering
633	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	6.2	2	20–	B.S. in Engineering
634	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	4.9	0	20–	B.S. in Engineering
635	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	5.8	1	20–	B.S. in Engineering
636	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	6.2	2	20–	B.S. in Engineering
637	Glass	N.Y.		11, 13, 18, 21, 26, 31, 36, 42, 43	9.0–10.0	5–10		
639	Education	N.Y.		10, 30, 40, 50, 60	9.0–12.0	5–15		Ph.D. in I.E.
640	Athletic Equip.	Ohio		11, 13, 16, 19, 26, 32–34, 42, 44	8.4–	5–6	30–40	MTM required
641	Athletic Equip.	Ohio		11, 13, 16, 32, 42	6.5–	3–4	25–45	MTM required
642	Rubber (Ind. Prod.)	Mass.		10, 11, 13–15, 20–22, 32, 36, 38, 43, 42	Open	3–7	25–40	College Graduate
643	Pharmaceutical	Ind.		10, 11, 13–15, 18, 19, 42, 43, 53	5.7– 6.5	0–3		I.E. or M.E.
644	Electronics	Dela.		11, 18, 30–38, 42	Open		Open	I.E. with some M.E.
645	Management Cons.	Minn.	45%	13, 31, 37, 43, 53, 55, 71, 72, 91	11.0–	5–	29–45	Engineering Degree
646	Steel Mfg. & Fabr.	Ala.		30	Open	5–	28–45	Exp. in Steel Fabr.
647	Printing	Eastern U.S.		30	Open		30–45	B.S. in I.E. or Equiv.
650	Chemical Proc.	W. Va.		15, 17, 48, 91	6.0– 7.2	0–2		B.S.I.E.
651	Propane Equip.	Ill.		10	5.4– 6.0	3–		Degree not required
652	Oil-Consulting	Middle East		10, 20, 30, 40, 70, 90	13.0–25.0	7–15	30–45	Degree
653	Research Lab.	Md.		30, 40 (Principal Engineer)		3–		B.S.I.E.
654	Research Lab.	Md.		30, 43 (Methods Analyst)		3–		B.S.I.E. or I.M.
655	Film	N.C.		10, 20, 30, 42, 43, 49, 53, 70, 73, 81	Open	0–5	21–30	I.E. Degree
656	Forgings, Stampings, etc.	Northeast		(Division Manager)	15.0–18.0	8–10	35–	I.E. Degree
657	Shirt Mfg.	Colo.		71, 90, 95	8.0–	8–	30–45	Shirt Mfg. & Records Exp.
658	Food Proc.	Minn.	Ltd.	10, 20, 30, 40, 81	5.2– 6.0	0–2	Open	I.E. or I.M. Degree
659	Machine Tool	Ohio		18,32	9.0–	10–	35–	M.E. or I.E. Degree
660	Consulting	N.Y.	×	10, 21, 36, 38, 91, 92	12.0–20.0	8–	35–45	M.E. or I.E. Degree
661	Research & Devel.	Ohio		50, 55, 70, 72	8.0–10.0	3–5	–35	M.B.A. or Equiv.
662	Papermaking	Pa.		Broad Experience	6.5– 8.0	0–3	21–30	I.E. Degree Pref.
663	Automotive	Pa.		31, 36, 38, 45, 53, 54, 71	6.7– 9.7	3–7	24–40	B.S. or B.A. Pref.
664	Automotive	Pa.		11, 14, 15, 18, 19, 22, 36, 45, 91	7.5– 9.7	4–12	23–45	B.S.I.E. Pref.
665	Automotive	Pa.		11, 14, 15, 18, 19, 22, 34, 36, 45	6.0– 7.9	1–6	23–31	B.S. or B.A. Pref.
666	Automotive	Pa.		11, 14, 15, 18, 19, 34, 36	5.5– 7.0	2–15	23–40	Degree not necessary
667	Soft Goods	Midwest		Manager of Mfg. Engineering	18.0–25.0		35–45	I.E. Degree—MTM exp.
668	Pharmaceutical	Ill.		40, 42, 44		0–5	–40	B.S. in Engineering
669	Mining & Refining	Ariz.		11–13, 18, 26, 28, 35, 36, 38, 48	6.5– 9.0		–40	
670	Garment Mfg.	N.J.		54, 71	Open	0–3		B.S.I.E.
672	Electronic	N.Y.		10, 30, 42, 43	–12.0	5–		M.S. or B.S. in I.E.
673	Electronic	N.Y.		11, 13, 36	–10.0	2–		Electronic Exp.
674	Chemical Processing	Va.		10, 11, 14, 26, 43	Open	3–5	Open	B.S.I.E.
675	Power Farm Machinery	Iowa		General	Open	2–5	30–45	I.E. Degree
676	Clay Products	Tex.	Ltd	12, 21, 36, 42, 43	5.8– 6.6	5–	28–35	I.E. Degree or Equiv.
677	Garment	Miss.		10, 11, 15, 18 (Chief I.E.)	10.0–15.0			Exp. in Garment Ind.
678	Garment	Miss.		10, 11, 15, 18	5.0– 8.0			Exp. in Garment Ind. Des.
679	Education	Conn.		Asst./Associate Professor				Doctor's Degree in I.E.
680	Pulp & Paper	Maine, Pa.		11, 31–37, 43, 49, 91	6.0–	Open		B.S.I.E.
681	Diversified Mfg.	Ill.	Ltd	10, 20, 91	7.5– 9.5	5–	30–50	I.E. Degree or Equiv.
682	Heavy Ind. Equip.	Wis.		10, 11, 13, 18, 21, 22, 90, 91	10.0–15.0	10–	35–	I.E. Degree
683	Plastics	Midwest		11, 19, 30–33, 35, 39, 40–44, 47, 48, 80	8.0–15.0	10+	30–45	I. E. Degree or Equiv.
684	Metal Fabrication	Mich.		36, 41, 53	10.0–15.0	4–	30–	I.E. Degree
685		Ga.	×	General (Exp. in Std. Cost)	6.6– 8.4	1–3		I.E. Degree
686	Lamp Mfg.	N.J.		10, 11, 14, 15, 20–23, 90, 92, 95	9.0–12.0		35–	I.E. Degree
687	Wood Furniture	Mo.		10, 11, 13, 21, 22, 36, 39, 47	7.0– 9.0	5	30–40	I.E. or M.E. Degree
688	Metal	Ind.		10, 13, 15, 30, 36, 40	Open	8–10	30–35	B.S.in Ind. Engineering
689	Corrugated Containers	Midwest		10–16, 21, 26, 60	6.0– 8.0	2–5	25–35	I.E. or M.E. Degree
690	Optical	N.Y.		10, 13, 19, 20, 36, 38, 42	9.0–12.0		35–45	I.E., M.E., and E.E. Degree
691	Navy	Hawaii		10, 20, 30, 40, 60, 70	7.5+	4		I.E. or Equiv.
692	Lab. Equip.	N.Y.		60–65, 71, 72	8.0–10.0	10	Open	
693	Education	Ohio		31, 37, 50	Open		30–50	Master's Degree Prev.
694	Communication	N.J.		10, 21, 30, 42, 43, 92	Open	5–7		Graduate Engineer
695	Electronics	Calif.		30, 32, 38, 39, 44	7.2	3		
696	Paint	N.J.		96 (Sales Division)	12.0–15.0			College Degree, Paint Exp.
697	Chemical	N.Y.		92	12.0			B.S. in Ind. Engineering
698	Hospital	D.C.		10, 30, 50, 70	Open	3–5	25–55	B.S. Pref.
699	Hospital	Mo.		Broad	10.0+	0–3		Ph.D. Preferred or M.S.
700	Navy	D.C.	25%	10–18, 50–52, 54, 71, 72	5.5– 7.7+	1–	21–50	College Degree
701	Pharmaceutical	N.Y.		37, 50, 52, 53	6.6– 7.8	1–3		I.E. Degree
702	Pharmaceutical	N.Y.		11, 13, 14, 15, 18, 36, 38	6.0– 7.0	0–3		I.E. Degree

* These 3 P# have openings in New York City, Detroit, Mich., Syracuse, N. Y., Indianapolis, Ind., and Cleveland, Ohio

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement (Production)
12	Methods Improvement (Office)
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds.
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

Entered as
second-class matter

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